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Meeting on Implications of Climatic Changes on
Mediterranean Coastal Areas (Island of Rhodes,
Kastela Bay, Syrian Coast, Malta and Cres/Losinj Islands)

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IMPLICATIONS OF EXPECTED CLIMATIC CHANGES ON THE SYRIAN COAST

UNEP
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PREFACE

As part of the efforts of the United Nations Environment Programme (UNEP) to analyze the potential implications of predicted climate change and to assist the governments in designing policies and measures which may avoid or mitigate the expected negative effects of this change, or to adapt to them, the Oceans and Coastal Areas Programme Activity Centre (OCA/PAC) of the United Nations Environment Programme (UNEP), in co-operation with several intergovernmental and non-governmental organisations, launched, co-ordinated and financially supported a number of activities designed to contribute to an assessment of the potential impacts of climate changes and to the identification of suitable policy options and response measures which may mitigate the negative consequences of the expected changes.

As part of these efforts, Task Teams on the implications of climatic changes were established in 1987 for six regions covered by the UNEP-sponsored Regional Seas Programme (Mediterranean, Wider Caribbean, South Pacific, East Asian Seas, South-East Pacific and South-Asian Seas) with the initial objective of preparing reviews of the expected impacts of climatic changes on coastal and marine ecosystems, as well as on the socio-economic structures and activities of their respective regions. Five additional Task Teams were established later, two in 1989 (West and Central African, and East African regions) one in 1990 (Kuwait Action Plan region) and two in 1992 (Black Sea and Red Sea).

During the work on the Mediterranean regional study, it was felt that while the general effects might be similar throughout the Mediterranean region, the response to these effects would have to be highly site-specific. Therefore in the framework of the Mediterranean Task Team six specific case studies were prepared (deltas of the rivers Ebro, Rhone, Po and Nile; Thermaikos Gulf and Ichkeul/Bizerte lakes) by the end of 1989. The first site specific case studies had concentrated on low lying deltaic systems including these of the Ebro, Rhone, Po and Nile rivers. Following their publication by UNEP, the reports of the Mediterranean Task Team were published commercially in Book form by Edward Arnold (Jeftic *et al.*, 1992, Climatic Change and the Mediterranean). In preparing these case studies it had become apparent that prediction of impacts was constrained by the absence of scenarios of future climates on a regional, sub-regional and local scale.

Accordingly the Climatic Research Unit of the University of East Anglia had been commissioned by UNEP to attempt to produce a Mediterranean Basin scenario and to develop scenarios of future local climate for the selected case study areas. The scale of existing Global Circulation Models is such that determination of future temperature and precipitation patterns at a local level involves considerable uncertainty concerning future conditions. Without such local scenarios assessment of future impacts involves even greater levels of uncertainty, reducing the value of such assessments for immediate planning and management purposes. A suite of scenarios for the Mediterranean region were developed using the output from the GCM's coupled with a finer scale meteorological database. Scenarios for local sub-regions and areas were subsequently developed for those areas which were to be examined in more detail during the second generation of case studies.

Using the experience of these initial case studies, in 1990 the preparation of the "second generation" of site-specific case studies was initiated for the island of Rhodes, Kastela Bay, the Syrian coast, the Maltese islands and the Cres-Losinj islands.

The objectives of these studies were:

- to identify and assess the possible implications of expected climate change on the terrestrial, aquatic and marine ecosystems, population, land- and sea-use practices, and other human activities;

- to determine areas or systems which appear to be most vulnerable to the expected climate change; and

- to suggest policies and measures which may mitigate or avoid the negative effects of the expected impact, or adapt to them, through planning and management of coastal areas and resources;

using the presently available data and the best possible extrapolations from these data.

The "second generation" case studies utilised the regional and local scenarios developed by the University of East Anglia in attempting to assess and evaluate the implications of future changes on specific islands and areas covered by the Mediterranean Action Plan.

The Task Teams assembled for each of the second generation case studies were composed of experts from a wide variety of natural and social science disciplines, with specific knowledge of the areas concerned. In addition, the national and local authorities responsible for planning and developments in these areas were brought into the work of the Task Team from an early stage. Thus for example the Municipal authorities of Rhodes included the work of the Task Team within their coastal development planning and the Municipal authorities of Cres and Losinj hosted several meetings of the Task Team.

In order to ensure that the Task Teams retained as wide a perspective of the problem as possible several UNEP experts on Climate Change Impact Assessment were included at all stages of the preparation of these individual assessments. The full list of Task Team members responsible for this report is given in the Appendix to this report. A final joint meeting of representatives of the Task Teams and UNEP experts was held in Malta in September 1992 at which the conclusions and recommendations of each Task Team were reviewed, compared and finalised.

This report represents one of the five site specific assessments covered during the course of this work. Whilst it is important to recognise that climatic changes and sea level rise will have an impact on future use and development of the Mediterranean coastal areas, it is equally important to recognise that the rate and scale of other sources of change, such as land-use patterns and demographic changes may be of more immediate concern in certain areas. In this context, actions designed to address the future impacts of climatic change and sea level rise must be founded on a sound basis of immediate actions designed to reduce the rate of adverse changes resulting from uncontrolled development and use of the Mediterranean coastal environment and its resources.

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EXECUTIVE SUMMARY

This project forms part of a wider, Integrated Planning Project for the Syrian coastal region undertaken within the framework of the Coastal Area Management Programme (CAMP) of the Co-ordinating Unit for the Mediterranean Action Plan. The report was prepared by a Task Team of national and international experts who were asked to evaluate the implications of future climatic changes and sea level rise on the coastal zone of Syria. The study was undertaken through a review of existing information and an expert evaluation of the likely implications of scenarios of future climate. These scenarios were developed by the University of East Anglia as part of the Mediterranean Co-ordinating Unit's wider activities in the field of climatic change impact assessment for the Mediterranean Basin.

The objectives of the study were: to identify and assess the eventual implications of expected climatic changes for the various natural aspects and resources of the Syrian coast; to determine the most vulnerable areas and ecosystems; and to suggest necessary policies and measures to avoid and/or mitigate the negative effects of climatic changes.

The Syrian coastal region occupies only around 2% of Syrian national territory but is home to 11% of the population and is of national importance in terms of agriculture, contributing about 11% to Gross National product. Energy production is high (35% of the national total) and some industrial activities such as cement production (38% of national production) and petroleum refining (50% of national total) are well developed in the region. International tourism is not well developed at present although the region has considerable potential in this regard. The coastal region is well supplied with transport links, including maritime, air and land based - roads and railways.

The climate is typically Mediterranean with cool dry winters and hot dry summers. The coastal region is dominated by the Jebel al Sahel mountain range which runs parallel to the coast some 20-40 km inland and affects the coastal climate. Rainfall increases from around 760-900 mm yr^{-1} in the coastal plains to a maximum of 2000 mm yr-1 in the mountains.

The soils of the area reflect the underlying geology which is dominated by limestones and dolomite and are of the typical Mediterranean red-brown types. Soils are generally deeper than 1m in the coastal plain. Fresh water supplies are adequate although some streams dry up during the summer. Irrigation is practiced on 16% of the cultivated land which covers in excess of a quarter of a million hectares.

The task team has established that there are considerable gaps in the data concerning many aspects of the coastal system, including amongst others, inadequate information on natural ecosystems, both marine and terrestrial on oceanography and beach dynamics. In addition the socio-economic projections are inadequate to enable the development of accurate planning scenarios beyond a short time frame.

Under scenarios of climatic change, temperatures will rise, more in the highland areas than in the coast with consequent impacts on natural and managed ecosystems and agricultural production. It is believed that the frequency of extreme events could increase, particularly the frequency of torrential rainstorms with consequent increases in soil and slope erosion. The rather uncertain scenarios of future rainfall suggest that the region may be slightly drier than at present.

Under scenarios of moderate sea level rise (20cm higher than present) the vulnerability of the Syrian coastal region may be increased but the Task team concluded that the impacts of such a rise would be of less significance than the impacts of non-climatic factors, including population increase and present development trends. Small enclosed "pocket beaches" may be the most vulnerable coastal types to increasing sea levels.

Although water resources are at present adequate the hydrological system was seen as one which is vulnerable to the impacts of climatic change and sea level rise, particularly since the demand for freshwater is likely to rise with population growth and increased agricultural production. Water quality may be adversely affected by salinization of groundwater; vegetation cover may decline and soil erosion may increase in a warmer world, although these systems will be more affected by the other sources of change indicated above.

In planning for and addressing future changes in the Syrian coastal region the Task Team recommends that:

- enhanced programmes of data acquisition be initiated to provide a sound information base on present systems and processes as the basis for future planning;

- integrated approaches to coastal zone planning and management be adopted which include *inter alia* evaluation of specific sites to sea level rise and evaluation of specific alternatives for protection and or zoning of development and infrastructure;

- environmental impact assessments be undertaken for all major developments in the region; and,

- programmes of air pollution abatement, water resource management, renewal energy use, international co-operation and vegetation/land use mapping be implemented as soon as practicable.

1. INTRODUCTION

1.1. Background

The second half of this century has witnessed a rapid and marked rate of development, in all aspects of economy and society. It has included developments in science and technology, the flourishing of industry, population growth, liberation of nations and the rise of living standards. A consequence of this unprecedented rate of change, which has also involved competition between states and individuals for greater prosperity and benefit, has been the degradation of natural ecosystems. This has occurred mainly as a consequence of: industrialization; the increased burning of fossil fuels; reduction of woodlands and the substitution of evergreen vegetation by seasonal crops.

These activities have caused carbon dioxide and other gases to accumulate in the atmosphere, in excess of their natural levels. These gases have the capacity to allow short wave solar radiation to penetrate to the earth's surface, and to prevent the long wave terrestrial radiation escaping back out to space. By trapping energy in the lower atmosphere, they keep the earth's surface warmer than would otherwise be the case. Since this natural "greenhouse effect" will be enhanced by the continuing increase of CO_2, the Earth's atmosphere is bound to become warmer.

Global temperatures have apparently increased by about 0.5 degrees Celsius over the last century, although neither in a continuous nor, spatially uniform way. This can be compared with oscillations of 1° or 2°C over the previous 10,000 years. Global mean sea level is thought to have risen by 10 to 15 cm in the last 100 years because of the thermal expansion of the oceans (responsible for 2-3 cm) and the melting of glaciers (for another 3-5 cm). The contribution of the Greenland and Antarctica ice sheets to this process is not yet known.

Some scientists think that these phenomena are related, while others believe that the effects of global warming will not be seen for many decades, or will be counteracted by other global phenomena and by positive or negative feedbacks such as: increased cloud cover; the actions of sulphates and aerosols; Carbon dioxide (CO_2) fertilization of natural forests; the response of the oceans; and increases in polar ice cover.

The increase in greenhouse gases (GHGs) could have a direct influence on agriculture, human health and natural ecosystems. The chlorofluorocarbon (CFC) gases have also been implicated in the depletion of the earth's ozone layer and in recent decades they have also begun to rival CO_2 in their contribution to the greenhouse effect.

The pre-industrial concentration of CO_2 was about 280 parts per million (ppm) by volume, of air. This concentration reached 340 ppm in 1980, it is now 365 ppm and could rise to 560 ppm sometime in the next century. The rate and extent of this rise will depend upon a number of non-natural factors, such as the future anthropogenic emissions of greenhouse gases and aerosols, which are a function of population and economic growth, and of energy policies.

After reviewing the available evidence on the greenhouse effect at a meeting in Villach, Austria, in October 1985, organized by the World Meteorological Organization (WMO), the United Nations Environment Programme (UNEP), and the International Council of Scientific Unions (ICSU), scientists from 29 industrialized and developing countries concluded that "major climate changes must be considered a plausible and serious probability".

They further concluded that: "many important economic and social decisions are being made today on major water resource management activities, such as irrigation, hydropower, drought relief; agricultural land use, structural designs and coastal engineering projects, and energy planning - that are based on the assumption that past climatic data, without modification, are a reliable guide to the future. This is no longer a good assumption".

They estimated that if present trends continue, the combined concentration of CO_2 and the other greenhouse gases in the atmosphere, would be equivalent to a doubling of CO_2 from pre-industrial levels, possibly as early as the year 2030, and that this could lead to a rise in global mean temperature "greater and more rapid than any in man's history". Current modelling studies and "experiments" show that as a consequence of CO_2 doubling, a potential rise in globally averaged surface temperature, of between 1.5 °C and 4.5 °C could occur, with warming becoming more pronounced at higher latitudes during winter than at the equator.

A serious concern is that global warming would cause a relative sea level rise of between 25 and 140 centimetres. A rise in the upper part of this range would inundate low-lying coastal cities and agricultural areas, and many countries could expect their economic, social and, political structures to be severely disrupted. It would also slow the "atmospheric heat-engine" which is driven by the differences between equatorial and polar temperatures, thus influencing rainfall regimes. Experts believe that crop and forest boundaries would shift to higher latitudes. The effects of warmer oceans on marine ecosystems, food chains and fisheries may be large, but are still largely unknown.

The 1990 assessment of the Working Group I of IPCC (for a "business-as-usual scenario") predicted the increase in global temperature to be about 1 °C by 2025 and 3 °C before the end of the next century. It also estimated that the magnitude of sea-level rise could be about 20 cm by 2030 and about 65 cm by the end of the next century. The 1992 IPCC update (Houghton *et al*, 1992) confirmed the 1990 estimate of a 0.3 °C temperature increase per decade, but reduced the range of uncertainties for a doubling of CO_2, on the basis of a large number of newly assessed physical and societal scenarios. The current "best estimate" average warming is of 2.5 °C (range 1.5 ° - 3 °C) for a doubling of CO_2; the sea level rise estimate is for a mean +12.5 cm by 2030; mean +22 cm by 2050; and a range of +28 - 60 cm by 2100. Even with this revised lower estimate the total sea level rise by 2030 would be between two and a half and five times that which has occurred over the last 100 years.

The countries that border the Mediterranean Sea would certainly experience many of the adverse effects of climate change resulting from global warming such as higher temperatures and changes of precipitation. Such changes will increase demands for irrigation and domestic fresh water, causing ground water depletion and salinization. Beach erosion and salt water intrusion into rivers and coastal aquifers would increase. Coastal farmland and aquaculture facilities could be lost. Torrential rains could increase the erosion of altered soils (Jaeger and Ferguson, 1990; WMO/UNEP, 1990). These changes would affect natural and managed ecosystems, and economic and social systems such as industry, beach tourism and public health.

The severity of these effects on the environment several decades from now, may be no greater than those already experienced under present day climatic conditions, as a consequence of mismanagement of land and population growth. The coastal region of Syria for example is already experiencing serious environmental problems such as: loss of soil fertility and erosion; salinization and depletion of groundwater; and, water and air pollution.

At present, there is no way of proving that unprecedented climatic changes will actually occur, or when they will occur. The key questions facing governments are: how much certainty should be required before any action is taken; and, when should such action be taken ? If governments wait until significant change is demonstrated, it may be too late for effective counter-measures, given the inertia of the global climate system. The very long time involved in negotiating international agreements on such complex, global issues has led some experts to conclude that it may be already too late.

Given the complexities and uncertainties surrounding the issue, it is urgent that the process of evaluation starts now. Thus, a three-track strategy is needed, combining:

- improved assessment of evolving environmental phenomena with monitoring of key environmental parameters;

- increased research to raise knowledge on the impacts of CO_2 together with the development of internationally agreed policies for the reduction in emissions of the causative gases; and

- the adoption of suitably timed strategies to minimize damage and to cope with the climate changes and rising sea level.

If the assumptions are wrong, and if by 2025 the climate remains more or less the same as today and if the predictions of future changes remain uncertain, nothing will have been lost by adopting this strategy. There is much to be done to reverse the present trends in environmental degradation, that are already taking place in the Syrian coastal region. We still need to know how to: stop land degradation; manage fresh water resources more effectively; reduce pollution of marine and fresh waters; and, mitigate the effects on the coastal environment of expanding cities and industries. We need to learn how to respond effectively to catastrophic events and to develop a different attitude to coastal land use which does not cause, or exacerbate, environmental problems.

The objective of this study is to examine the possible consequences of rising temperature and sea levels and of changed climate for the coastal region of northwest Syria, and to estimate what effects such changes could have on natural and managed ecosystems, and on the social conditions, economy and health of the population.

The possibility of a significant alteration of climate must be taken into consideration in view of: the current population explosion; the increased use of coastal areas for tourism, agriculture, harbours, and industries; and the limited natural resources of the region, particularly fresh water and good soil. The effects of climate changes may prove to be among the major problems facing the marine and coastal environments in Syria, in addition to those related to development.

As a continuous activity within the process of integrated planning and management of the Syrian coast, carried out by the Mediterranean Action Plan of UNEP (UNEP-PAP,1992) in cooperation with the Syrian General Commission for Environmental Affairs, a Task Team to evaluate the implications of climatic changes for the Syrian coast was established in July 1991. Its aim was to identify and assess the possible implications of global warming for the terrestrial, aquatic and marine ecosystems, population, land use and sea use practices, and for other human activities. The Task Team was also required to determine areas or systems which appear to be the most vulnerable to the expected climatic changes; to make recommendations relevant to the management of coastal areas and resources; and to recommend on the planning and design of major long-term infrastructure.

1.2. Basic facts about the coastal region of Syria

The Syrian coastal zone which separates the Mediterranean shoreline from the arid zones of the interior (Figure 1) is transitional in both spatial and functional terms, and this characteristic has influenced the social and historical development of the region (Damascus Univ., 1990). Although relatively small, comprising little more than 2% of the national territory, the coastal region has 11 percent of the total population of the country, and its contribution to economic activities including agriculture, some industrial sectors, tourism, energy production, and transport is relatively high. Due to its economic importance, the limited physical space and fragility of its ecosystems, the coastal region of Syria and its resources deserve special attention, in terms of both their present and future development.

The total length of the coast is about 180 km and most basic resources such as agricultural land, and economic activities, infrastructure, large urban settlements, and natural scenic and cultural values are concentrated into a relatively narrow strip, about 10 km wide.

Morphologically the coastal region includes a coastal lowland; a middle zone of hilly country (100-400 m alt.); and the mountains of Jebel as Sahel (Jebel Saheilligheh) (400-800 m). The latter lie N-S and stretch for 50 km, some 20-40 km inland, rising gradually northward to Jebel Nabi Matta (1563 m).

The coastal zone includes: beaches, dunes, wadis and valley mouths, and cliffs, as well as in parts, anthropogenically shaped coastlines such as urban seafronts and port/terminal facilities, which together comprise some 10% of the total. Plains areas occupy about 60% and, hills some 30% of the coastal zone. Stable sandy beaches occur north of Lattakia (Wadi Qandeel area) and south of Tartous, where a long straight beach extends all the way to the Lebanese border. High dunes are especially well developed south of Lattakia, between the mouth of Nahr al Kabir and Nahr el Sonuber.

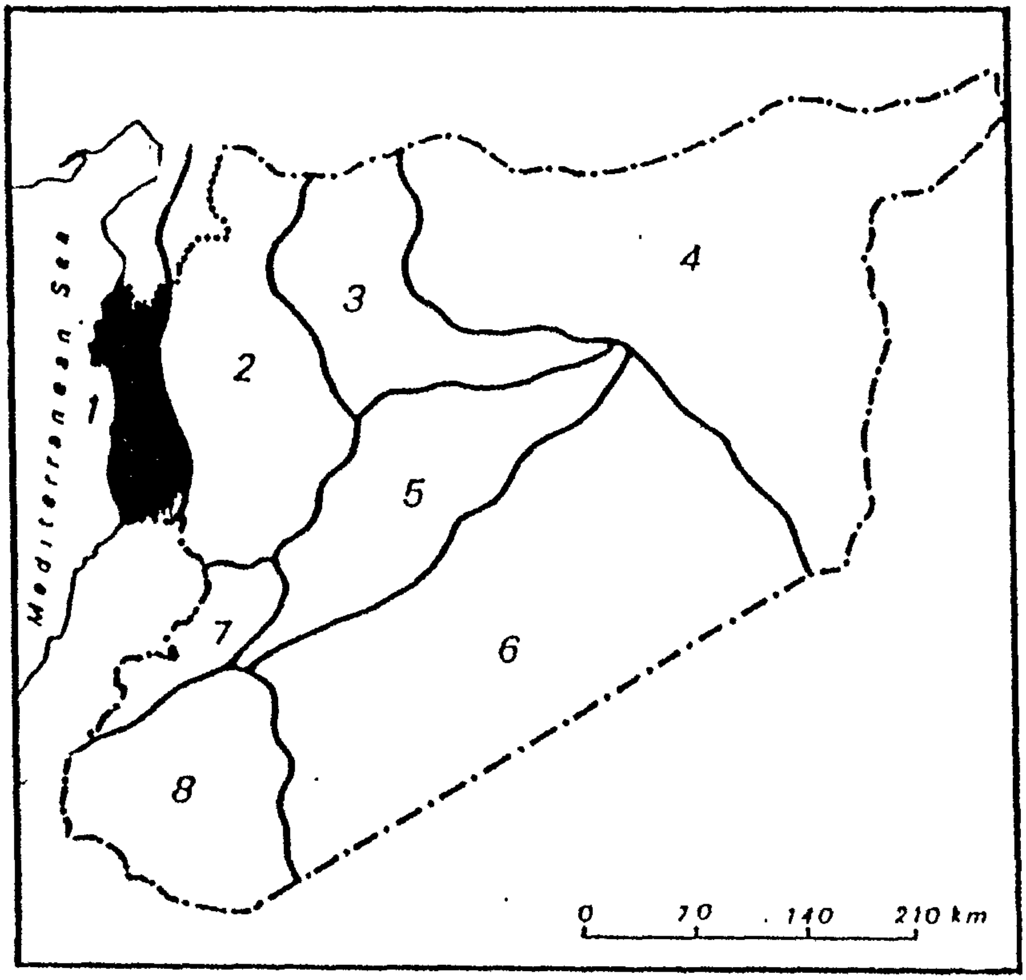

Figure 1 - The coastal region (black) in relation to the other geographical regions of Syria

The sharp morphological distinction between mountains and hills where erosion prevails and, the coastal depositional lowlands is one of the natural environmental features that determines the different types of land use in the coastal region and hence, the impact of man on the environment.

The soils of the coastal region reflect the underlying geology, which is dominated by calcareous rocks, including limestone, dolomite, and marls. The typical red and brown Mediterranean soils predominate, containing clay and loam and the most common and fertile soil is the *terra rossa*, especially in the coastal plain where it is generally greater than 1 m in depth.

The climate of the coastal region is Mediterranean of the humid or, subtropical subtype, with cool, mild winters and hot dry summers. In general temperature decreases from west to east and from south to north. The average annual temperature range is 19°-20°C at the coast, 14°-17°C in the mountains. August maxima are 29-30 and 24-28 and winter minima are 7-9 and 1.4-5.3 at the coast and in the mountains respectively. Frost is rare, but snow is rather frequent on Jebel Saheiligheh above 1200 metres elevation.

The amount of precipitation increases from the lower hills to the upper mountain slopes; from 760-900 mm yr^{-1} in the coastal plain to 1575 (maximum 2000 mm) on the mountains. Heavy downpours and thunderstorms are common in association with the passage of cyclones over the area. In the coastal zone relative humidity is moderate to high (60-80%) in summer, and potential evapotranspiration is also high (1600 mm) compared to 1200 mm in the mountains. Although overall, the climate is mild, there is considerable inter-annual variability in temperature and especially in precipitation, with an irregular sequence of wet and dry years.

The hydrology and fresh water resources of the coastal region are adequate given the relatively high rainfall and extensive groundwater storage. With the exception of the north and south Nahr al Kabir rivers, which are 96 and 50 km long respectively, most of the streams have short courses and are dry in the summer. There are many springs, of which the Al Seen spring is the most important, with a discharge of 7 - 25 m^3 sec^{-1} providing water, for irrigation (63%) and urban use (33%) (Iacovides, 1991).

A number of freshwater supply projects are in the development or planning stages and it is expected that on completion they will achieve complete coverage of urban, industrial and agricultural demand. Nevertheless there are deficiencies in the water supply system which include: water losses due to inefficient distribution networks; and pollution of both surface and underground waters from farm and village, agricultural, and industrial wastes.

Detailed studies of marine hydrology along the Syrian coast are still at an early stage of implementation and information is generally scanty. The Mediterranean deepens rapidly off the Syrian coast with only a very narrow continental shelf (0-200 m). The bathymetric contour of 500 m depth lies only 10 km off-shore. Tidal range is low, storm waves are generally moderate, but occasional exceptional events are known to have caused damaging storm surges; salinity and water temperatures are high in summer.

Despite the extent of cultivation, almost one third of the surface of the coastal region is covered by natural or man-made woods and forests. The most common trees are pine and oak. Typical natural woodland occurs along some river banks near their mouths, and is composed of a distinctive flora and fauna.

The population of the coastal region in 1991 was 1,381,000, largely rural (66%) and the urban population totalled 465,000 people. A notable increase in population occurred during the period 1960-90, due not only to a high natural growth rate (3.3%) but also to internal migration from the interior to the coast. Estimates suggest that the population could double again by the year 2020.

The principal economic activity of the Syrian coastal region is agriculture which contributes about 11% to the total GNP of Syria. It is likely to retain this prominence in the future, because of high local and external demands for agricultural produce. There are practically no natural mineral resources of economic importance, except for building materials, and fishing is of minor importance with a production of only 1,400 tons in 1990.

Cultivated land constitutes 51% (265,000 ha) of the land area of the region and 16% of this is irrigated (Figure 2). The main crops are: cereals, predominantly wheat; fruit including citrus, apples, plums, and grapes; olives; and vegetables, notably greenhouse crops of tomatoes, peppers, cucumber, and egg plant grown in the Tartous region. Other crops include tobacco, peanuts and potatoes.

The industrial output of the coastal region contributes about 10% to the national total. The region supports high production of cement, 38% of the country's total; 50% of oil refining; and, 35% of electricity generation. Other industries which are mainly concentrated in Lattakia, include production of wood panelling, electric motors, and textiles, and processing of food, tobacco and building materials.

The coastal region has a good network of roads, including a four lane highway that connects Lattakia with Tartous and Homs, and rail links with Homs and Halep. The modern and spacious ports of Lattakia and Tartous are very important commercial links for import-export; Tartous and Banias are oil terminals; and Tartous has special phosphate loading facilities.

The coastal region of Syria has a number of tourist attractions: a cooler climate during the summer than the rest of the country; beaches and coastal scenery; and, historical sites of interest. At present, tourism is not a major economic activity. 238,000 tourists visited the area in 1990 of which 15% were foreign, and this represents only 15% of the total tourists visiting Syria. Expansion of existing tourist facilities is planned. The summer attraction of the coast has led to the development of tourist homes and apartment blocks, in some areas constructed illegally and/or too close to the water's edge.

At present the coastal region of Syria is beset by a number of environmental problems, some due to natural climatic factors, like the damage caused by drought, torrential rain and floods, spring frost or hail, strong dry winds, and by exceptional storm surges at the coast. Three quarters of the region are affected by strong to severe soil and slope erosion.

Other problems are of anthropogenic origin. Pressures on the environment have been caused by the increasing rate of population and economic growth, with consequent demands for space, for towns and industries. Increased demands for agricultural production have resulted in increased use of pesticides and fertilisers. In addition there are problems of deforestation due to cutting for increased grazing and arable land; water and air pollution (Figure 3); waste disposal and resultant health hazards.

Without adequate planning and management such problems will be exacerbated by the further concentration of activities in the coastal zone, especially in the narrow strip between the shoreline and the railway and motorway which link Lattakia and Tartous (Abdul Salam, 1985).

1.3. Assumptions and methodology

1.3.1. Basic assumptions

The main objective of this study is to assess the potential impacts of climatic changes following global warming, on the environment and the socio-economic setting of the Syrian coastal region. The report attempts to identify those aspects of the physical, biological and human systems that would be most vulnerable to unprecedented increases in temperature; to changes in rainfall and evaporation; and, to sea level rise.

The basic premise of this report is that a global warming due to "greenhouse" gas increases is probably inevitable, and that it could be of unprecedented proportions, with far reaching consequence for the region's climate, and for sea level.

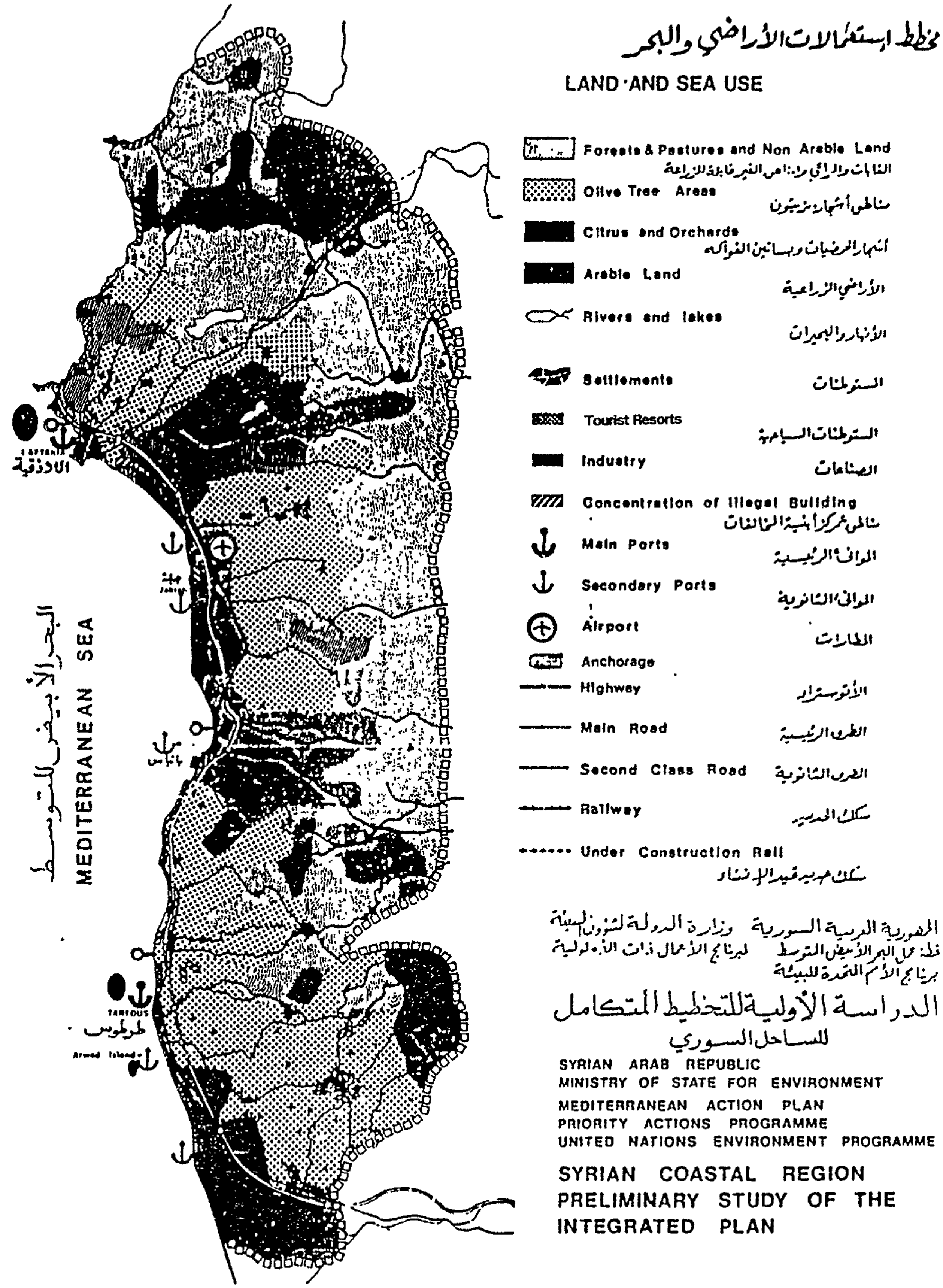

Figure 2 - Land and sea use in coastal Syria

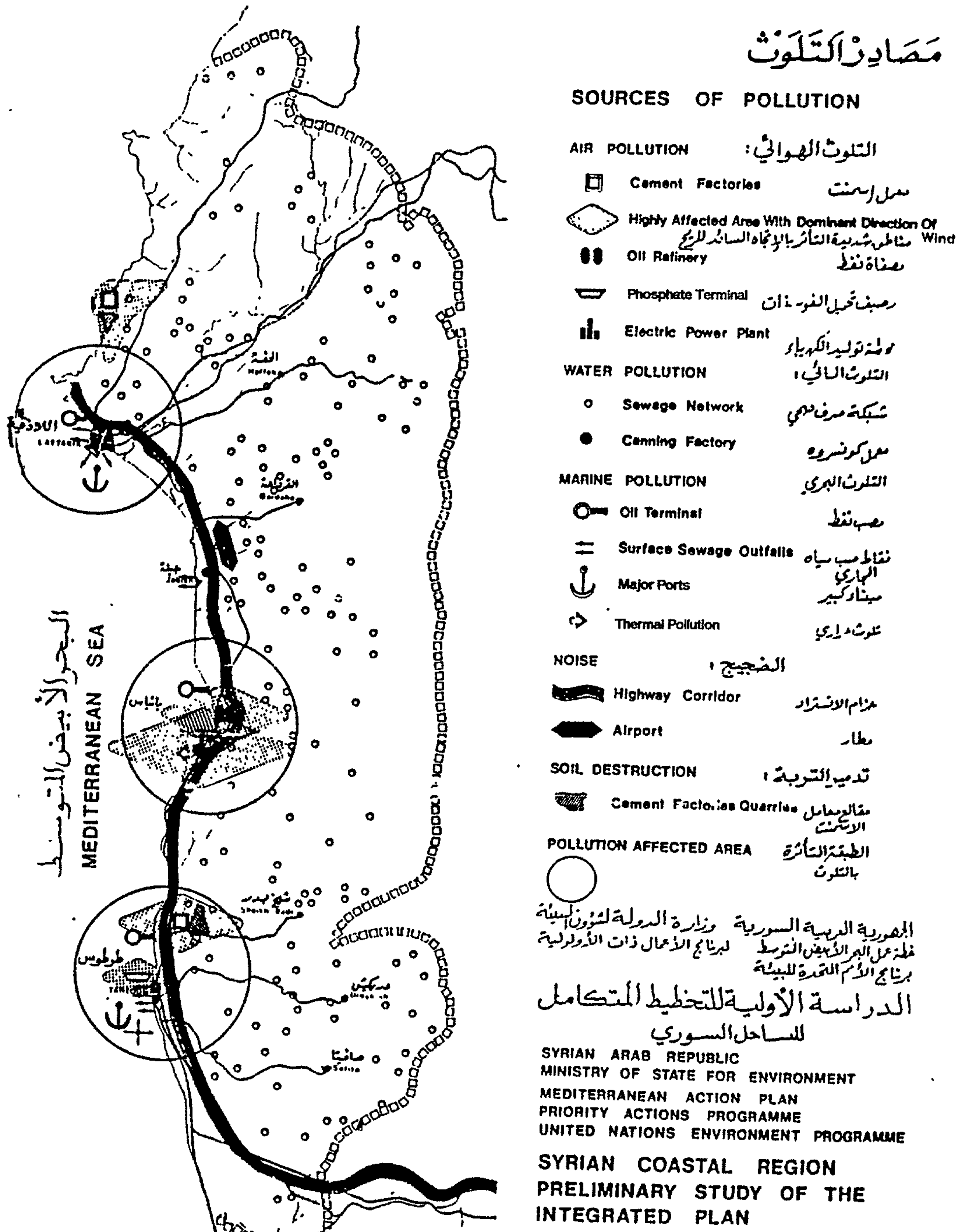

Figure 3 - The sources of pollution in the Syrian coastal zone

At present, predictions of the magnitude of warming are still affected by a high degree of uncertainty and the implications of either positive or negative feed-backs are unknown, such that there is still no absolute confidence that climate will change, other than in the way it has changed over the recent past (Lamb, 1988). It is not considered too early to examine the possible implications for society and national resources of scenarios of future change, and to evaluate how scenarios of future climates would affect the management of the coastal region during the next few decades.

The assumptions used in this study are based on the 1990 conclusions of IPCC (Houghton *et al*, 1990) that, unless measures for greenhouse gas emission control are implemented by the world community, the global average temperature will rise by 1 °C by 2025, and by 3 °C before the end of the 21st century.

Scenarios of changes of temperature and precipitation for the Mediterranean Basin, based on General Circulation Models (GCMs) were discussed by Wigley (1992). GCMs are one of the available tools for estimating changes at a global level as a consequence of CO_2 doubling. However, it is estimated that predictions using GCMs could be of ± 50% uncertainty, due to positive and negative feedbacks in the climate system which are currently not included in the models. These uncertainties are particularly large in the case of regional and sub-regional level predictions. The models are not forecasts and a major deficiency is their inability to accurately reproduce present-day regional weather patterns and, to offer consistent predictions of rainfall distribution. GCM models cannot yet be used to construct area-site specific scenarios.

Nevertheless General Circulation scenarios can provide a means to investigate the likely consequences of CO_2 doubling, in association with a statistical method in which the regional and seasonal patterns of the past climatic variables are used to construct more local scenarios.

The term "scenario" is used to describe a picture of the climatic future, often constructed from GCMs. Such a scenario is one feasible realization of the climate systems evolution drawn from the ensemble of possibilities. It differs from a forecast or prediction in being easier to develop but the uncertainties are much greater. Despite these problems it has to be accepted that the results of GCMs offer the only available tool for developing regional climatic scenarios.

Regional climate impact analysis is faced with the problem of having to interpolate real climatic changes on small scales with the large scale generalised statistics generated by GCMs. This down-scale transformation has been called the climate inversion problem. There are two approaches that may be used to solve it, either: to couple a local/regional dynamic model with a GCM; or, to determine the most probable local/regional structure of a climate variable from a GCM, based on large scale climate.

The method used by the Climatic Research Unit of the University of East Anglia in the report prepared for UNEP/MAP is illustrated in Annex I (Climatic Research Unit, 1992). The conclusions are that temperature could increase by 0.8-1.2 °C in the lowlands and by 1.0-1.6 °C in the mountains, for each 1 °C increase in global mean temperature. These scenarios (Table 1) suggest that rainfall could increase appreciably in winter and spring, but decrease in the summer and autumn.

Another source of uncertainties in impact analysis stems from present limited capabilities for making predictions about the behaviour of natural and social systems under normal or stressed conditions, such as those that may be caused by changing climate conditions.

Although as a methodological convenience we have adopted the scenarios developed on the basis of the above premises (Table 1), it should be noted that:

1. the scenarios relate only to temperature and precipitation projections, resulting from numerical exercises that are valid only as state-of-the-art working tools. The GCM predictions of future changes in climate will be subject to constant revision, as more data on emissions and feedbacks become available. The operative scenarios can be modified in the light of such revisions for any degree of global change;

TABLE 1

Scenarios for the predicted climate change in Syria deduced from scenarios suggested by IPCC and the University of East Anglia

SCENARIOS	TIME HORIZON		
	2030	2050	2100
IPCC GLOBAL			
Temperature	+1.8°C	-	+2 to +5°C
Sea level	+ 18 cm +/- 12 cm	-	+ 65 cm +/- 35 cm
IPCC Southern Europe			
Temperature	+2°C winter +2 to + 3°C summer	-	-
Rainfall	+ 0 to + 10% winter - 5 to + 15% summer	-	-
Soil moisture	- 15 to - 25% summer	-	-
Univ. East Anglia Med	for each °C Global change		
Rainfall	+ 3% winter - 3% summer		
UNEP Task Teams			
Temperature	-	+ 1.5 to + 3°C	-
Sea level	-	+ 24 to 52 cm	-
Univ. East Anglia for Syria	for each °C Global change		
Temperature (1)			
Annual	+ 0.8 to + 1.2°C (2) + 1.0 to + 1.6°C (3)	as for 2030	as for 2030
Winter	+ 1.0 to + 1.2°C (2) + 1.0 to + 1.2°C (3)		
Spring	+ 0.8 to + 1.0°C (2) + 1.0 to + 1.2°C (3)		
Summer	+ 1.1 to + 1.2°C (2) + 1.2 to + 1.6°C (3)		
Autumn	+ 1.0 to + 1.2°C (2) + 1.2 to + 1.4°C (3)		
Rainfall (4)	for each °C Global change	as for 2030	as for 2030
Annual	0 to - 2 % (2) 0 to - 2% (3)		
Winter	+ 2 to + 6% (2) 0 to + 2% (3)		
Spring	+ 2 to + 4% (2) 0 to + 2% (3)		
Summer	0 to - 22% (2) 0 to - 22% (3)		
Autumn	- 2 to - 18 % (2) - 2 to - 18% (3)		

SCENARIOS	TIME HORIZON		
	2030	2050	2100
Operative Scenarios for Syria			
Temperature [1]			
Annual	+ 1.44 to 2.16° C [2]	+ 1.2 to 3.6°C [2]	+ 1.6 to 6.0°C [2]
	+ 1.8 to 2.88° C [3]	+ 1.5 to 4.8°C [3]	+ 2.0 to 8.0°C [3]
Winter	+ 1.8 to 2.16°C [2]	+ 1.5 to 3.6°C [2]	+ 2.0 to 6.0°C [2]
	+ 1.8 to 2.16°C [3]	+ 1.5 to 3.6°C [3]	+ 2.0 to 6.0°C [3]
Spring	+ 1.44 to 1.8°C [2]	+ 1.2 to 3.0°C [2]	+ 1.6 to 5.0°C [2]
	+ 1.8 to 2.16°C [3]	+ 1.5 to 3.6°C [3]	+ 2.0 to 6.0°C [3]
Summer	+ 1.98 to 2.16°C [2]	+ 1.65 to 3.6°C [2]	+ 2.2 to 6.0°C [2]
	+ 2.16 to 2.88°C [3]	+ 1.8 to 4.8°C [3]	+ 2.4 to 8.0°C [3]
Autumn	+ 1.8 to 2.16°C [2]	+ 1.5 to 3.6°C [2]	+ 2.0 to 6.0°C [2]
	+ 2.16 to 2.52°C [3]	+ 1.8 to 4.2°C [3]	+ 2.4 to 7.0°C [3]
Sea level	+ 18 +/- 12 cm	+ 38 +/- 14 cm	+ 65 +/- 35 cm
Rainfall [4]		0 to - 6% [2]	0 to - 10% [2]
Annual	0 to - 3.6% [2]	0 to - 6% [3]	0 to - 10% [3]
	0 to - 3.6% [3]	+ 3 to + 18 % [2]	+ 4 to + 30% [2]
Winter	+ 3.6 to + 10.8% [2]	0 to + 6% [3]	0 to + 10% [3]
	0 to + 3.6% [3]	+ 3 to + 12% [2]	+ 4 to + 20% [2]
Spring	+ 3.6 to + 7.2% [2]	0 to + 6% [3]	0 to + 10% [3]
	0 to + 3.6% [3]	0 to - 66% [2]	0 to - (110)% [2]
Summer	0 to - 39.6% [2]	0 to - 66% [3]	0 to - (110)% [3]
	0 to - 39.6% [3]	- 3 to - 54 % [2]	- 4 to - 90% [2]
Autumn	- 3.6 to - 32.4% [2]	- 3 to - 54% [3]	- 4 to - 90% [3]
	- 3.6 to - 32.4% [3]		

(1) Temperature change calculated from East Anglia scenario
(2) Coastal plain
(3) Montane region
(4) Percentage changes in rainfall should be related to present values

2. the factors considered (temperature and precipitation) are not fully reflective of climate change, since climate encompasses other elements and factors, many of which (e.g. pressure, general circulation) go well beyond the region of the eastern Mediterranean. Precipitation is a function of wind, which transports water vapour, and topography (land-sea relationships, land elevation). Equally coastal dynamics is related to atmospheric circulation (a function of temperature-pressure distribution on a large scale), as influenced by the earth's rotation;

3. the figures taken as the basis for impact assessment are averages. Climate (the climate 'norm') can be expressed by averages, but it must be understood that these represent +/- 30 year average values of meteorological elements (pressure, winds, temperature, humidity, precipitation, cloud cover, etc). Averages say nothing about the variability over a range of time and space scales. Variability and change are a fundamental characteristic of climate, and are the most significant aspects in assessing its impact (O'Hare and Sweeney, 1990); and

4. The degree of confidence in regional climate patterns based directly on GCM output remains low and there is consistent evidence regarding changes in climate variability or storminess. The following comments by Wigley (1992) should be kept in mind in interpreting the use of the operative scenarios:

"Substantial global warming is virtually certain, but the attendant changes in climate at the regional level are highly uncertain. Indeed for precipitation we are as yet unable to specify even the sign of regional changes with any reliability".

"For direct assessments of impacts at regional scale (or smaller), details of future changes are needed - not only for temperature, but for a variety of climate variables. At present, our capability for predicting these details is limited".

"In the Mediterranean Basin, the greenhouse gas changes will change the large scale characteristics of climate and will affect temperatures and temperature patterns in the sea and surrounding land areas. The precise patterns of future climatic change, however, will be controlled to a considerable extent by the way these effects are modulated by geography".

"The impacts of any global-mean climatic change will depend on the regional details of changes in a wide variety of climate variables and in changes in the interannual variability of these variables. At present we are unable to predict these changes".

1.3.2. Methodology

The general procedure followed by the Task Team is outlined in Figure 4. It includes the following steps in line with its objectives to explore the possible implications of the given premises and to identify the policy options that could be used to prevent or to adapt to a changed climate situation:

(a) the identification of the factors of each physical and socio-economic aspect, that are climate sensitive;

(b) an evaluation of how the physical parameters of the environment would change, at different time horizons in the future (eg. 2030; 2050; 2100);

(c) an estimate of the consequences of these changes for society and economy, that is, which social conditions would be affected (directly) by climate, and (indirectly) by the alteration of the primary economic activities that are based on natural resources (water and soils; weather; beaches and scenery; and, marine and/or terrestrial biocenosis of economic importance); and

(d) an assessment of what sensible recommendations for action could be given to government experts, officials, and decision-makers, in the light of: the time scales involved; the degree of present uncertainty; the priority; and, the relative cost of their implementation.

The first task for the Team was to collect all available information on the coastal region of Syria that would be relevant to the study. This phase was facilitated by work already carried out for the Integrated Coastal Zone Project (UNEP-PAP, 1992). Sufficient relevant data were found to be available to characterize the socio-economic systems, much less so for the natural environment.

Greater difficulties were encountered in the evaluation of impacts, especially in applying the operative scenarios in a practical way. Firstly, the present uncertainty surrounding the prediction of temperature and sea level changes, and the responses of the physical-biological systems, make a fair appraisal of the magnitude of the environmental and socio-economic consequences highly speculative. As frequently stated in the 1990 IPCC review, relatively few studies have been made so far about the responses of factors and elements of natural systems to temperature and CO_2 increases.

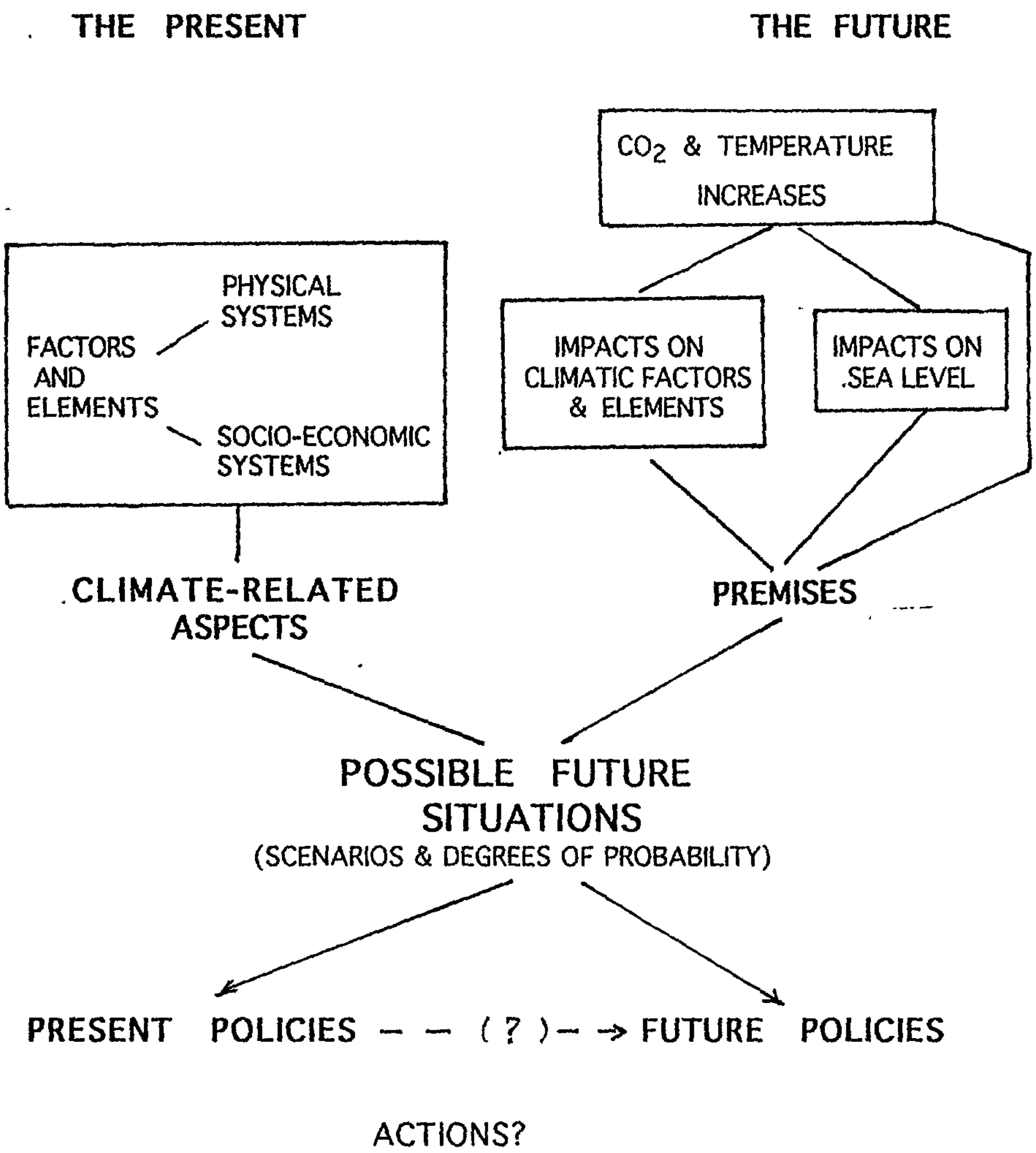

Figure 4 - Methodology flow-chart for the work of the Syrian Task Team

In the second phase, there is also uncertainty surrounding: the future level of coastal development and use; the changes to local/world economic relations and social habits; and, future changes which might be generated by technological innovations. The impacts on natural environments, will be different from the largely indirect impacts on the fields of anthropogenic concern namely on: agriculture and animal husbandry; water resources; shoreline stability; living standards and human welfare. In regard to the economic consequences other factors such as market demand are involved that are not only difficult to predict but are also not climate sensitive.

The final challenge facing the Task Team was that of making practical suggestions for actions to prevent, or to adapt to, the changes in climate and sea level that could occur during the next century.

The translation of hypotheses into practical, that is, sensible action, ought to be based on documented potential consequences and their degrees of probability, as well as on all elements of altered climate. However, there is at present a high level of uncertainty regarding the temperature, rainfall, and sea level scenarios and it will be another decade at least before better forecasts can be made of the trends in these parameters.

Thus, in recommending actions, the issue of the time scale involved becomes essential. Does one analyse the consequences of given premises for the physical and socio-economic parameters of today, as though the changed conditions would occur tomorrow, and not many decades hence; or, should one try to make (largely imaginative) hypotheses of impacts in 50-100 years time ?

While the application of given premises to present conditions within the framework of assumed climate changes (20-30 years) is possible, projections of the state of the population and economy are more difficult to make other than over the short-term (UNEP, 1988).

Is a policy of preventive actions today, practical, other than to prevent or minimise greenhouse gas emissions ? Actions to prevent future specific consequences for environments and society in the Syrian coastal region cannot be taken today because, such consequences cannot be defined with the degrees of certainty, that would justify immediate policy and financial commitments.

The best solution appears to be to consider a time scale that is reasonable from the perspective of the present generation such as that used for land-based developments including the construction of large infrastructure such as motorways, ports, tourist centres, and dams, which are intended to last at least 30-40 years.

Recommendations for action are made therefore in the context of what may be sensible to do during this period, to increase preparedness for an eventual drastic change of climate; and at the same time contribute to the urgent need for sound coastal zone management and for environmental and resources protection, in the face of population growth and economic development.

2. IDENTIFICATION AND ASSESSMENT OF THE POSSIBLE CONSEQUENCES OF CLIMATE CHANGE

2.1. Climate

2.1.1. General features

The climate of the eastern Mediterranean region is determined by dynamic factors that are related to the circulation of the atmosphere and air masses within and outside the region, including:

1. the semi-permanent pressure systems in each season including: the cold Siberian high pressure in winter; the Indian Monsoon low pressure in summer; and, the heat lows of North Africa (Khameseen) (Figure 5);

2. the mid to high latitude westerlies;

3. the subtropical high pressure system (an extension of the Azores high at the surface and sub-tropical at high altitude);

4. the sub-tropical jet stream and polar front jet;

5. the moving depressions and associated weather, and the extension of the Sudan trough from time to time in winter and in the transitional seasons;

6. the Mediterranean as the main source of moisture, in addition to its being a positive or negative thermal source (warm surface in relation to cold polar air masses, a cool surface in relation to the tropical masses); and

7. orography, which plays a role in the general climate and has local effects.

The influence of the above interacting factors determines the source of air masses; the centres of cyclogenesis; and, disturbance or stability of weather in each season (Met. Dept, 1979).

2.1.1.1 Winter (December to February)

This is a mild and rainy season, during which the coastal region is mainly affected by westerlies and depressions, either carried by general westerly wind streams or by depressions formed over the Genoa and Cyprus areas of the Mediterranean. The formation of depressions is partly determined by the transitory excursions of the polar front jet and by the European upper trough modified by land-sea temperature contrasts, which favour cyclogenesis over the warm sea. Eastward penetration of depressions may be determined by the zonality of upper flow and/or the strength of the Siberian (Eurasian) high pressure centres.

A strong European trough in winter is often associated with low index, meridional flow situations (blocking over western Europe) and with movement of the sub-tropical jet. The position of the polar front jet is important in determining areas of cyclogenesis and cyclonic tracks. The usual southerly excursion of the polar jet could well result in increased rainfall over the region and more frequent penetration of cyclones eastward toward the Syrian coast.

The westerly sub-tropical jet stream becomes very well established at higher velocity with its axis over the southern Mediterranean coast; there is evidence of depressions being steered by it (Figure 6).

Cloudiness, rain and sometimes snow over the mountains, particularly when the area is affected by northeasterly to westerly winds, are associated with the passage of depressions. They are followed by cold wind and a considerable temperature drop, when Syria and its' coastal region are under the influence of cold air masses that block these depressions.

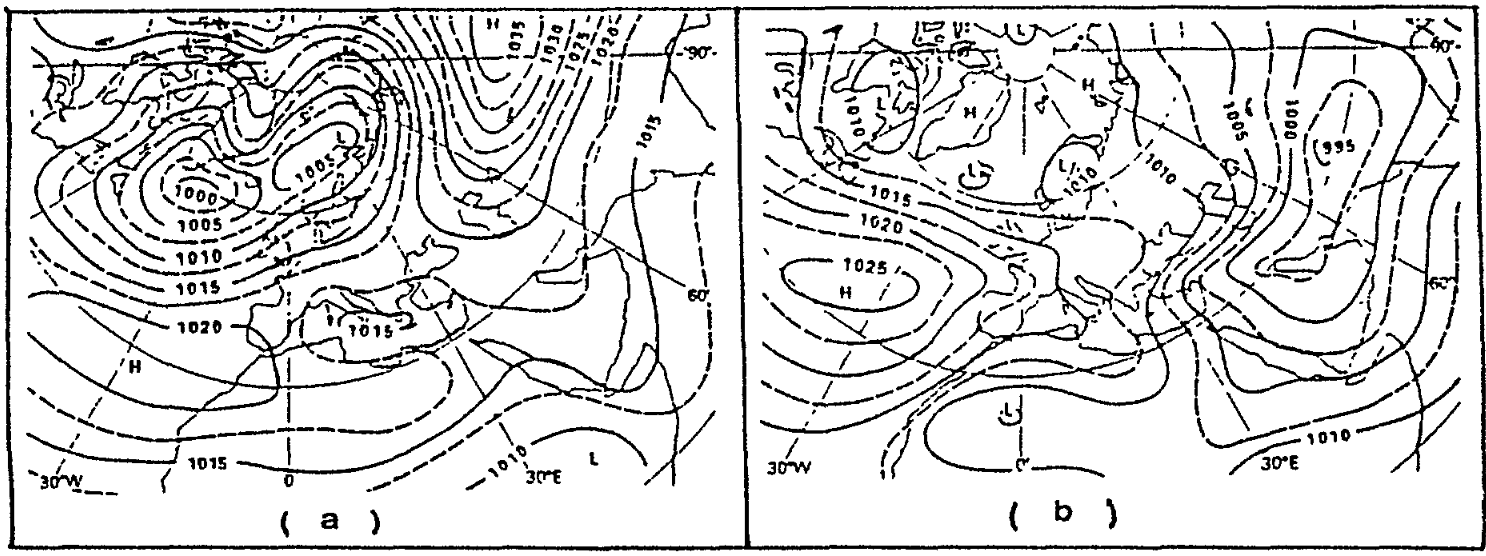

Figure 5 - Distribution of pressure fields: (a) average pressure for January (1951-1966); (b) average pressure for July (1951-1966)

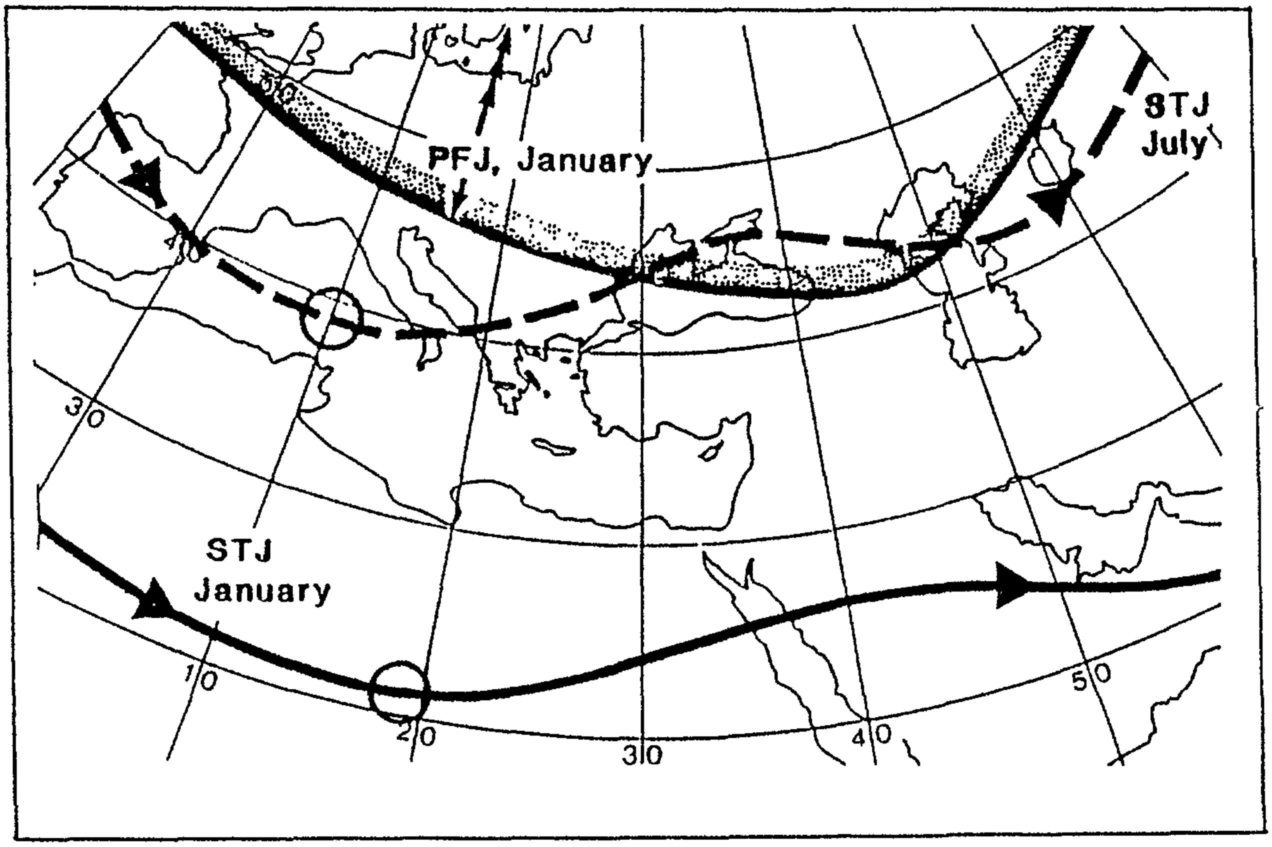

Figure 6 - Mean positions of the polar front jet (PFJ) and subtropical jet (STJ) in winter and summer (Wigley and Farmer, 1982)

In addition to these conditions, Syria is also affected in winter by the extension of the Siberian high (which is the source of genuine cold polar air mass) and of anticyclones over Europe. These conditions bring clear skies, bright sunshine and stable conditions with a considerable decrease in temperature.

2.1.1.2 Summer (June to August)

The spring transitional conditions may extend a week or 10 days into June before the onset of the normal summer conditions which are warm and dry. The westerlies become weaker and retreat northward with the polar front jet and the depressions tend to pass north of Turkey and along the Black Sea. Subsequently, western Syria is free of cyclonic disturbance and rain.

During summer the region may come, at lower altitudes, under the influence of the Indian Monsoon, with weaker westerlies at higher levels. Except when the trough of the monsoon low pressure extends far to the northwest, which occurs infrequently at present, the air absorbs moisture during its passage over the sea and on blowing landward, raises the relative humidity. Initially this is less stable and is likely to be affected by the passage of a low pressure system, or by passage of the European frontal conditions. Where the two types of air meet over the sea, given the added factor of high topography, a major convergent movement can develop leading to uplift. Under these conditions unusual marked summer precipitation occurs.

The sub-tropical Azores high pressure dominates the Mediterranean most of the season, thus blocking the passage of westerly depressions over the sea. A further contributing element would seem to be the presence of a sub-tropical jet over Asia Minor and the Caspian, which is accompanied by sub-tropical high pressure with upper level extension northwards.

Consequently, the features of summer weather are generally clear skies with occasional cloud from time to time, no precipitation, except occasionally, and high temperatures.

2.1.1.3 Spring (March to May) and autumn (September to November)

Two notable features are observed during these transitional seasons. The first is the Sudan trough, which swings northwards and southward with the passage of waves over the eastern Mediterranean.

The second is the passage over Syria of the thermal Khameseen depressions, which form in the lee of the Atlas mountains in north Africa. They are accompanied by hot south-westerly to south easterly winds with suspended dust from the desert. Sometimes they are followed by rain.

2.1.2 Precipitation

As a consequence of the prevailing atmospheric conditions, the geographic location, the elevation and the N-S extension of Jebel as Sahel, the coastal region forms the first western land barrier facing the easterly Mediterranean climatic influences, especially the winter cyclones and the prevailing westerlies of the upper air movements. Jebel as Sahel thus provides an important topographic feature causing orographic uplift of moisture laden air resulting in cyclonic and orographic precipitation in the coastal area. Consequently, Jebel as Sahel receives the highest annual total precipitation not only in the coastal region but also for the whole of Syria.

Although it is generally true that winter is the main rainy season, the distribution of precipitation also shows high percentage values in spring and autumn. During the winter months the region receives 51-60 % of total rainfall; in spring 20-30 %; and in autumn, 17-20 %. In some years summer rainfall occurs in June, but at most this does not constitute more than 1-2 % of the annual total.

Over the northwest mountains, above 1000 m and above 1200 m in the southern parts of Jebel as Sahel a considerable proportion of precipitation falls each year as snow, remaining more than 10 days in mid-winter. Heavy rain after a snow fall results in torrential floods. Snow and cold weather cause communications breakdown and damage. Below 600 m snow is rare and remains less than one day.

The average annual total precipitation ranges from 761 to 900 mm on the coastal plains, 1,134 to 1,575 mm on the mountains. Some highly placed mountain meteorological stations have recorded occasional maxima over 2,000 mm (e.g. Jabit Burghal in 1975, 2,156.5 mm; Al Qadmous in 1968, 2,130 mm).

Table 2 shows the monthly and annual average precipitation values for some stations of the coastal region while Figure 7 shows the distribution of average annual total precipitation and Figure 8, illustrates the annual number of days with precipitation more than 1 mm.

The main features of the precipitation system in the coastal region are:

1. rain occurs in two to six day periods interrupted by longer, sometimes two week periods, with no rain;

2. heavy downpours and thunderstorms occur during rainy periods, associated with the passage of cyclones; and

3. there are critical differences in annual total rainfall amounts between dry and wet years (Table 3).

These characteristics have negative influences on: agriculture, in particular dry land cultivation; the water supply; and, soil cover (see section 2.2.). Despite these limitations, the annual average and annual minimum rainfall in the region are higher than the minimum required for dry land cultivation, both in the plains and in the mountains.

2.1.3. Temperature

Temperatures in the coastal region are influenced and moderated by two main factors: the proximity of the Mediterranean Sea; and, the elevation of the northwest uplands and the Jebel as Sahel mountain chain, in addition to the fundamental climatic control exerted by latitude.

The mean annual temperatures are 19 - 20 ° C in the coastal plains; 14 - 17 ° C in the mountains (Table 4 and Figures 9 a and b).

The average maximum temperature occurs in August, the hottest month in the region, reaching 29 - 31 ° C along the coastal strip and 24 - 28 ° C in the mountains (Table 5, Figure 10).

Most stations on the coast and in the plains have recorded absolute maximum temperatures higher than 40 ° C; mountain stations below 1,000 m have absolute maxima between 37 and 40 ° C; while those above this altitude have recorded absolute maxima of less than 36 ° C (Table 6 and Figure 11).

The winter temperatures are low. The annual average minimum temperature is between 14 and 16 ° C in the coastal lowlands; between 9 and 13 ° C in the uplands. The average minimum temperature for January is 1.4 - 5.3 ° C in the mountains, 7 - 9 ° C in the plains (Table 7 and Figure 12).

Temperatures below zero are normal in the mountains, where the annual averages of absolute minimum temperatures range between -1 and -6 ° C. The mean annual number of days with temperatures below zero is 17 days and colder temperatures are generally found in the northern part of the mountain area (Table 8 and Figure 13).

The western foothills and coastal plains have annual averages of absolute minimum temperatures between 0 and 2 ° C. Temperatures below freezing are not recorded, except for a few hours on severe winter days, when the absolute minimum temperatures in the coastal plains reaches as low as -1 to -3 ° C. The montane stations below 1000 m have recorded absolute minima of between -4 and -9 ° C, while montane stations above 1000 m may reach as low as -11 ° C.

TABLE 2

Mean total monthly precipitation (mm) for the coastal and montane meteorological stations of the Syrian coastal region based on data for the period 1955 to 1984

	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec	Annual
Coastal Montane Stations													
Kassab	281.4	234.1	185.0	122.4	59.6	20.5	5.3	16.4	22.7	102.5	130 8	280.8	1461.5
Sheikh Bader	266.1	210.2	192.3	118 2	41.3	8.2	2.6	2.0	12.1	89.6	147.7	259.3	1349.6
Qadmous	259.9	195 1	207.2	122.5	44.8	12.7	2.3	2.7	18 6	91.8	133.9	232 4	1323 9
Qastal Ma'af	200.6	167.3	154 3	110.7	55 6	11.9	2.4	12.9	23.1	99.4	104.3	218.0	1160 4
Safita	211.3	183.5	157.4	109 6	21.5	3.9	1.9	2 2	19.1	78.9	133.8	210.4	1133.5
Jabit Burghal	286.2	254.8	232.4	174.8	74.6	16.5	4.8	5.9	18.5	109.1	131.5	272.8	1574.9
Slenfeh	243.0	205.8	213.4	133.2	58.5	24.5	6.1	7.7	28.6	68.2	112.4	286.2	1387 6
Coastal plains Stations													
Mina Al Baida	161.9	120.4	95.1	54.2	25.9	6.3	1.4	4.8	15.7	71.9	94.2	184.9	841.7
Lattakia	184.2	101.8	97.1	48.9	20.8	4.8	1.1	2.5	8.7	69.7	89.7	167.7	797.0
Jableh	199.1	123.7	102.0	57.0	37.2	8.7	3.1	1.7	4.4	104.3	45.6	159.1	895.9
Tartous	188.2	125.5	107.1	57.9	16.9	11.9	0.7	0 8	9.6	63.0	110.1	183.1	874 8
El Seen	170.0	132.3	122.3	59.6	23.4	5.2	1.4	2.2	7.8	70.4	96.8	184.3	875.9
Banias	148.3	101.5	118.7	56.5	15.8	2.3	0.6	0.3	1.5	63 6	117.9	134.3	761.3

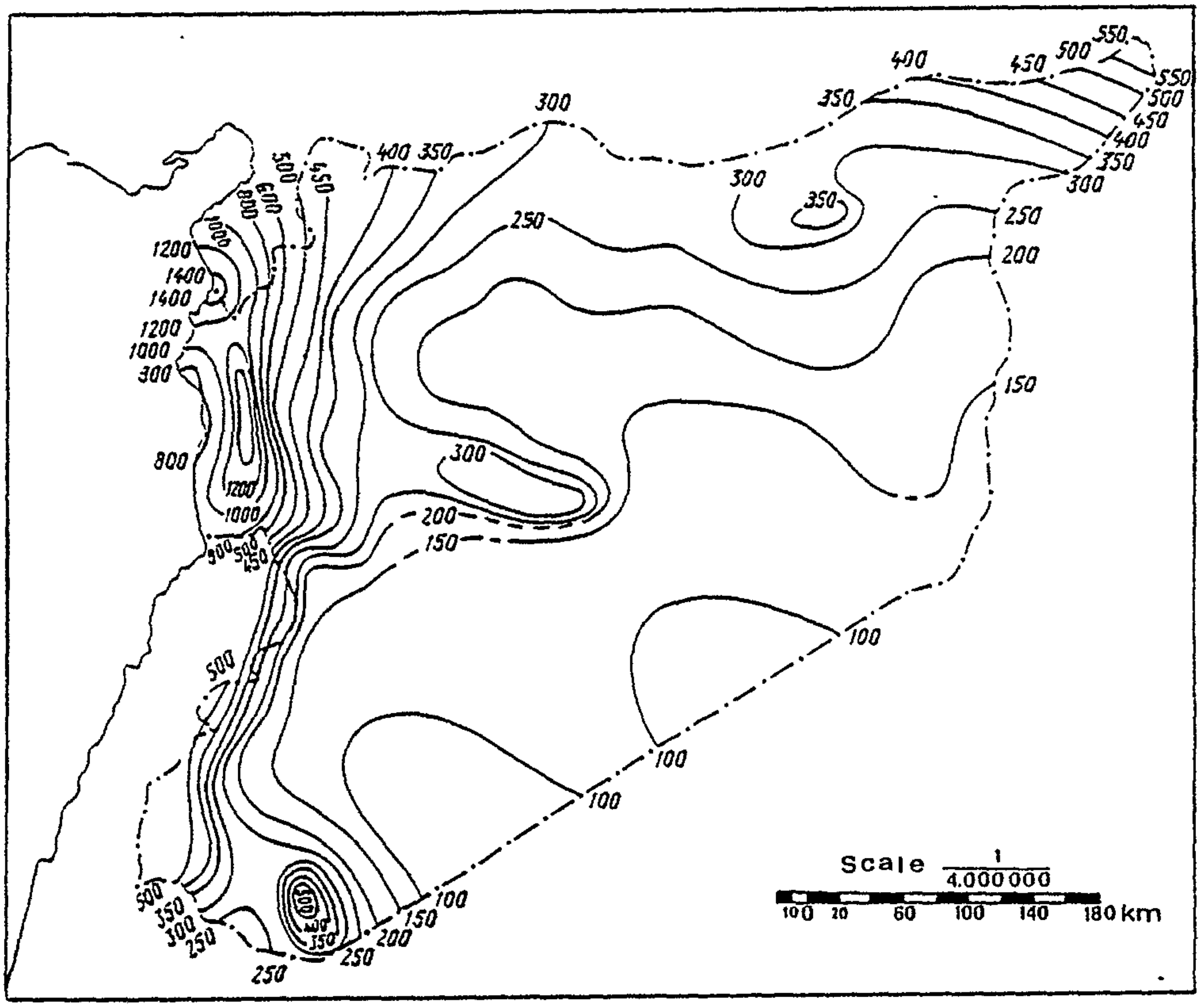

Figure 7 - Average total annual precipitation (mm) for the period 1955 to 1984

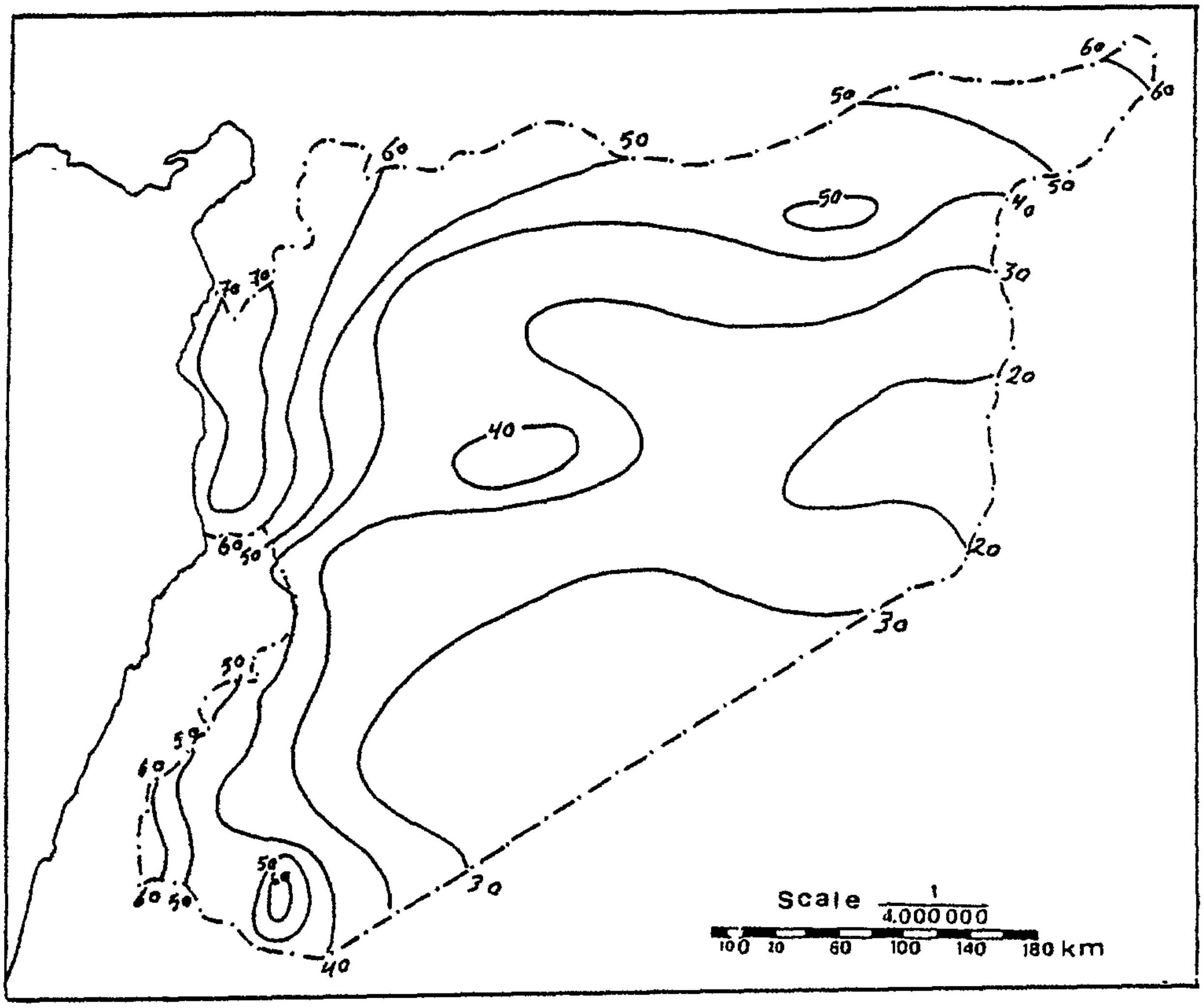

Figure 8 - Average No of days per annum with precipitation > 1 mm, for the period 1955 to 1984

TABLE 3

Variation in total annual rainfall (mm) between wet and dry years over the period 1955 to 1984

	Dry years		Wet years	
Coastal Montane Stations	Year	Rainfall mm	Year	Rainfall mm
Kassab	1972	654.2	1968	1981.3
Sheikh Bader	1972	817.2	1967	1777.6
Qadmous	1972	767.2	1968	2130.8
Qastel Ma'af	1972	543.1	1968	1559.4
Safita	1972	639.9	1968	1717.5
Jabit Burghal	1972	1042.7	1963	2156.5
Slenfeh	1972	588.9	1976	1967.8
Coastal Plains Stations				
Mina al Baida	1972	334 6	1968	1255.2
Lattakia	1972	434.3	1968	1099.6
Jableh	1990	325.6	1976	1180.0
Tartous	1990	360.4	1968	1234.3
El Seen	1972	457.2	1978	1444.7
Banias	1982	466.2	1987	1002.9

TABLE 4

Mean monthly surface air temperature for the coastal and montane meteorological stations of the Syrian coastal region based on data for the period 1955 to 1984

	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec	Annual
Coastal Montane Stations													
Kassab	5 8	6.7	10.1	13.8	17.5	20.6	22.0	22 5	21.4	18.4	13.1	7.8	15 0
Sheikh Bader	8.1	9.2	11.9	15.3	18.9	22.1	23.6	24.1	22.4	19.4	14.7	9.9	16.6
Qadmous	5.5	6.1	9.0	12.7	16.8	19 6	21.1	21.4	20.4	17.5	13 0	7.9	14.3
Qastal Ma'af	7.6	8.7	11.5	15.0	18.5	21.7	23.3	23 8	22.3	19.4	14.8	9.5	16.3
Safita	9.2	10.0	12.9	16.3	20.0	22.9	24.4	24.9	23.8	21.2	16 8	11.5	17.8
Jabit Burghal	5.6	6.4	9.3	12.7	16.3	18 6	20.6	21.5	20.0	17 6	12.0	7.6	14.0
Slenfeh													12.5
Coastal plains Stations													
Mina Al Balda	11.6	12.4	14.4	17.3	20.4	23.9	26.4	27.0	25.3	22.0	17.4	13.3	19.3
Lattakia	11 7	12.8	14.7	17.7	20.8	23 8	26.2	27.0	25.5	22.3	17.4	13.2	19.4
Jableh	11.4	12.1	14.4	17.1	20.1	23.4	25.7	26.2	24.7	21.3	17.6	13.4	18.9
Tartous	12.1	12.7	14.8	16.8	20 5	23.7	26.0	26.7	25.1	22.6	17.7	13.8	19.4
El Seen	12.3	12.7	15.1	18.0	20 9	24.0	26 1	26 8	25.1	22.0	17.7	13 9	19.5
Banias	12.9	13 4	15.3	17.7	20 8	24.1	26 3	27 1	26.3	22.9	19.0	14.9	20.1

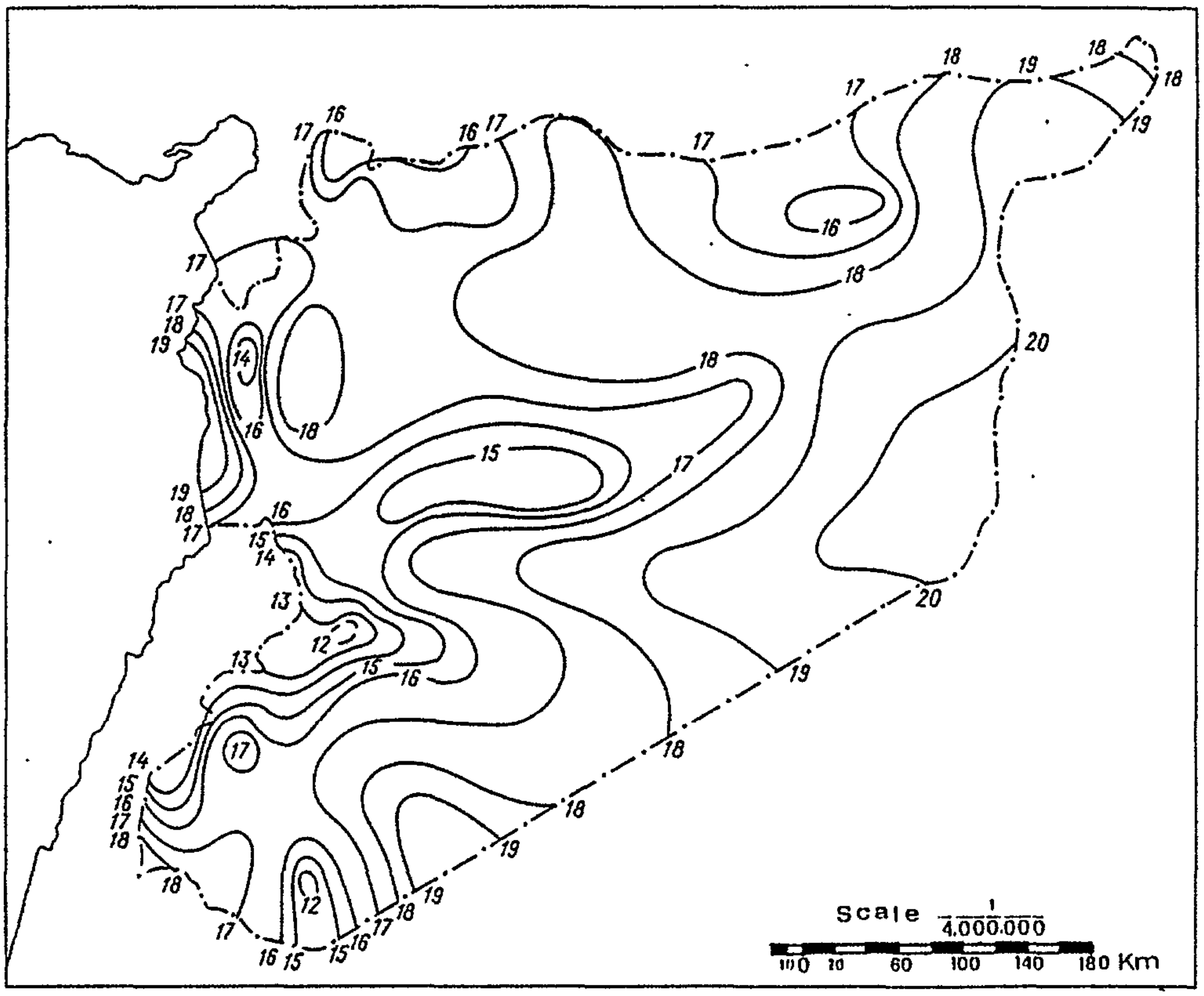

Figure 9a - Mean annual surface air temperature (° C) for the period 1955 to 1984

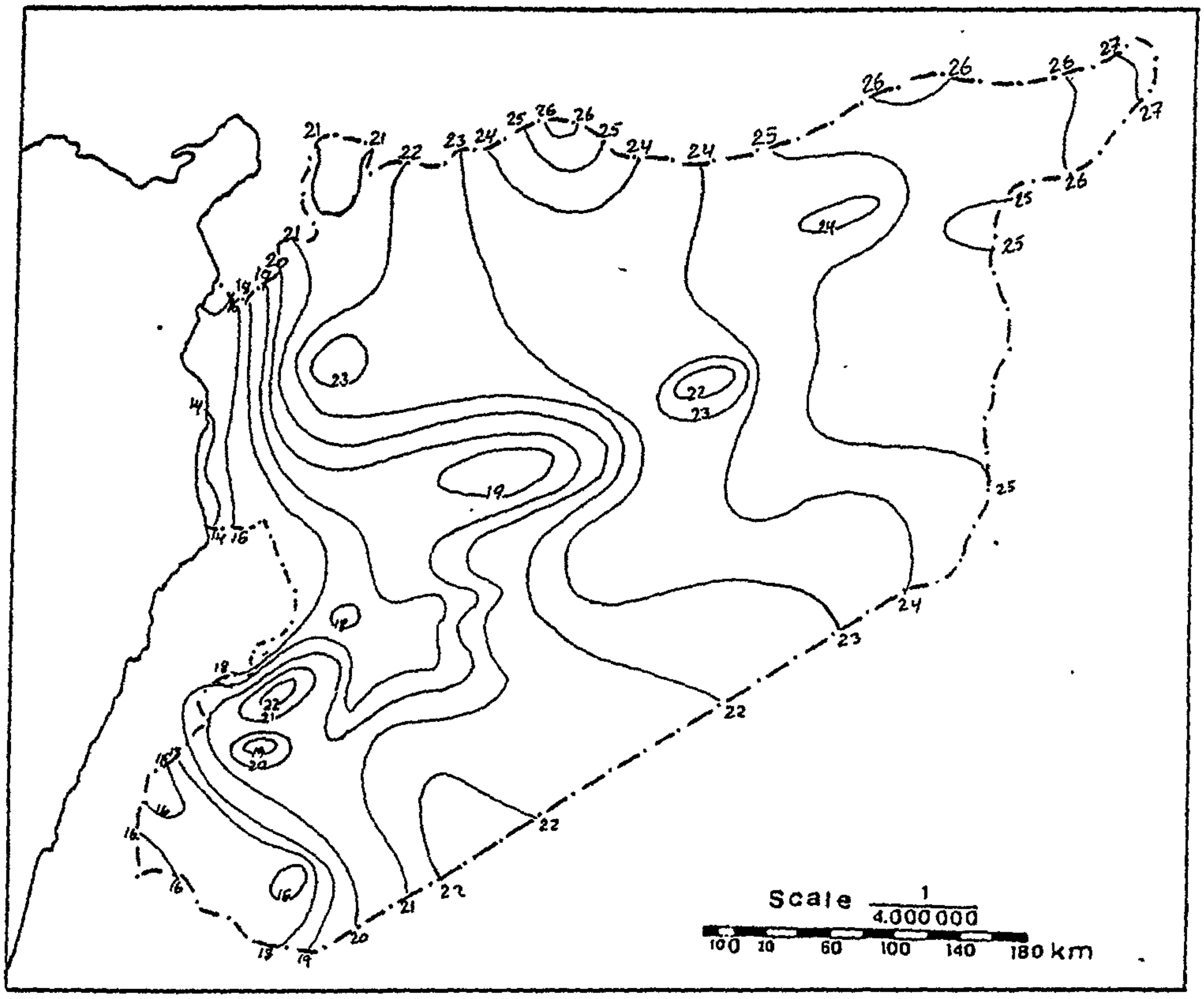

Figure 9b - Mean annual range in temperature (° C) for the period 1955 to 1984

TABLE 5

Mean monthly maximum temperatures (° C) for coastal stations in Syria based on data for the period 1955 to 1984

	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec	Annual
Coastal Montane Stations													
Kassab	8 4	9.7	13.4	17.3	21.4	24.6	26 2	26 9	25.7	22.3	16.8	10.7	18 6
Sheikh Bader	11.6	13.2	16.1	20 0	24.6	27.6	28.8	29.5	28.2	25.0	19.9	13.7	21.5
Qadmous	7.9	9.0	12.0	16.0	20.5	23.7	25.3	25 8	24.2	21.2	16.2	10.5	17.7
Qastal Ma'af	10 5	12 4	15.6	19.4	23.3	26 7	28.5	29 0	27.5	24.2	18.8	12.5	20 7
Safita	12.6	13 7	16.9	20.6	24.8	27.7	28.9	29 8	29.0	26 2	21.0	14.8	22.2
Jabit Burghal	8.5	9.7	12.8	16 3	20.7	23.8	25.4	26.0	25.3	22.1	16.4	10.8	18.2
Slenfeh	6.5	7.4	10.7	14.9	19.4	22.5	24.0	75.1	23.4	19.9	14.5	9.2	16.5
Coastal plains Stations													
Mina Al Baida	15.5	16 6	18.7	21 6	24 6	28.0	30 3	31.3	24.8	27.0	22.3	17.4	23 5
Lattakia	15 4	16 3	18.2	21.3	24 0	25.8	28.4	29.6	29.0	26.2	21.8	17.5	22.3
Jableh	15.4	16.7	19.4	22.1	25.7	28.4	30.3	31.0	29.9	27.2	23 5	18.3	24.0
Tartous	15.9	16.5	18.6	12.7	24.7	27.3	29.1	29.9	24.2	26.6	22.3	17.8	24.2
El Seen	16.9	17.5	19.7	22.6.	24.7	28.3	30.0	30.9	30.2	27.6	23.7	18.6	24.2
Banias	16.2	17.8	18.9	21 9	25.2	27.6	29 7	30.5	30.8	27.3	23 3	18.5	24.0

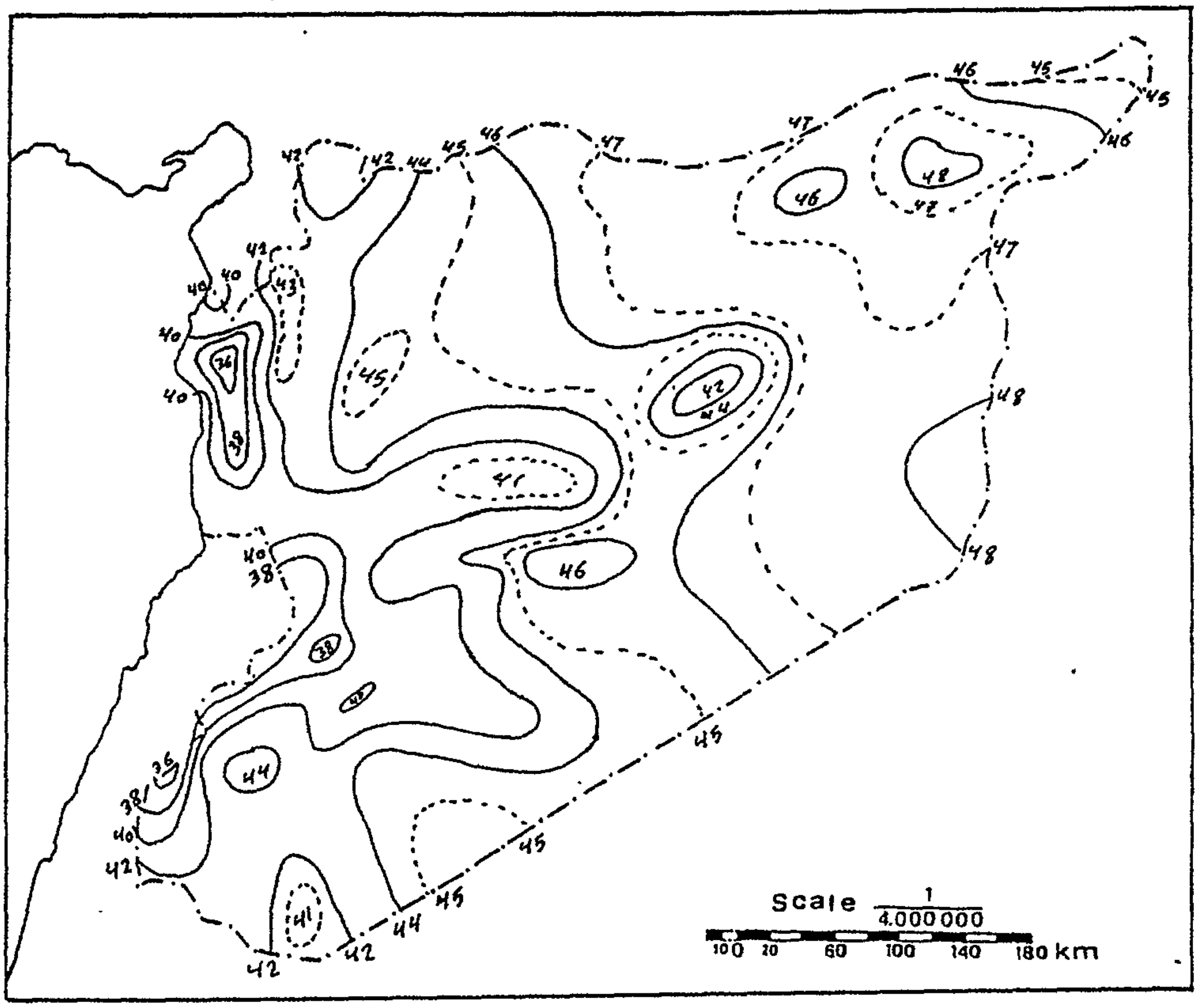

Figure 10 - Mean annual maximum temperature (° C) for the period 1955 to 1984

TABLE 6

Absolute maximum temperatures for coastal stations in Syria

	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec	Annual
Coastal Montane Stations													
Kassab	17.5	20.0	24.0	31.5	33.5	35.5	36.0	39.0	36.8	31.5	27.0	22.0	39.0
Sheikh Bader	22.0	25.4	31.4	37.3	38.5	39 0	36.5	39.0	37.5	35.4	39.7	25.6	39.0
Qadmous	22.5	21.5	23.5	32.0	34.0	35.0	38.0	36.5	35.0	31.0	28.0	23.2	38.0
Qastal Ma'af	18.6	20 0	27.1	33.8	37.0	38.4	36.0	40.2	37.3	34.1	28 8	23.1	40.2
Safita	22.8	25.0	31.6	35.7	38 0	40.8	39.8	40.5	39.9	37.4	31.5	25.7	40.8
Jabit Burghal	22.0	21.3	26.5	32 0	33.0	35 0	33.5	37.0	36.0	33.0	28.2	22 5	37.0
Slenfeh	19.5	20.5	25.5	30 0	32.0	32.0	32.0	35 0	33.0	31.0	25.4	20.0	35.0
Coastal plains Stations													
Mina Al Baida	24.3	25 0	32.2	36 8	37.0	38.3	34.2	42.7	34.5	37.6	31.2	26 0	42.7
Lattakia	23 5	24.8	30 8	35.0	38 8	36.8	38.3	35.9	38.2	36.8	35.3	24.8	38.8
Jableh	23 0	26.7	33.8	35.1	37 6	37.8	40.7	37.8	38.8	34.5	31.7	26.6	40.7
Tartous	27.1	22.5	32.4	39.0	40.2	41.0	38.0	39.7	38.0	38.0	33.6	26.5	41.0
El Seen	28.5	28.0	34.0	38.5	39.0	40.2	41.3	40.4	41.0	38.2	35.0	27.3	41.3
Banias	23.1	27.0	32.3	34.5	38.5	39.0	37.0	38 0	39.2	36.2	32.5	38.0	39.0

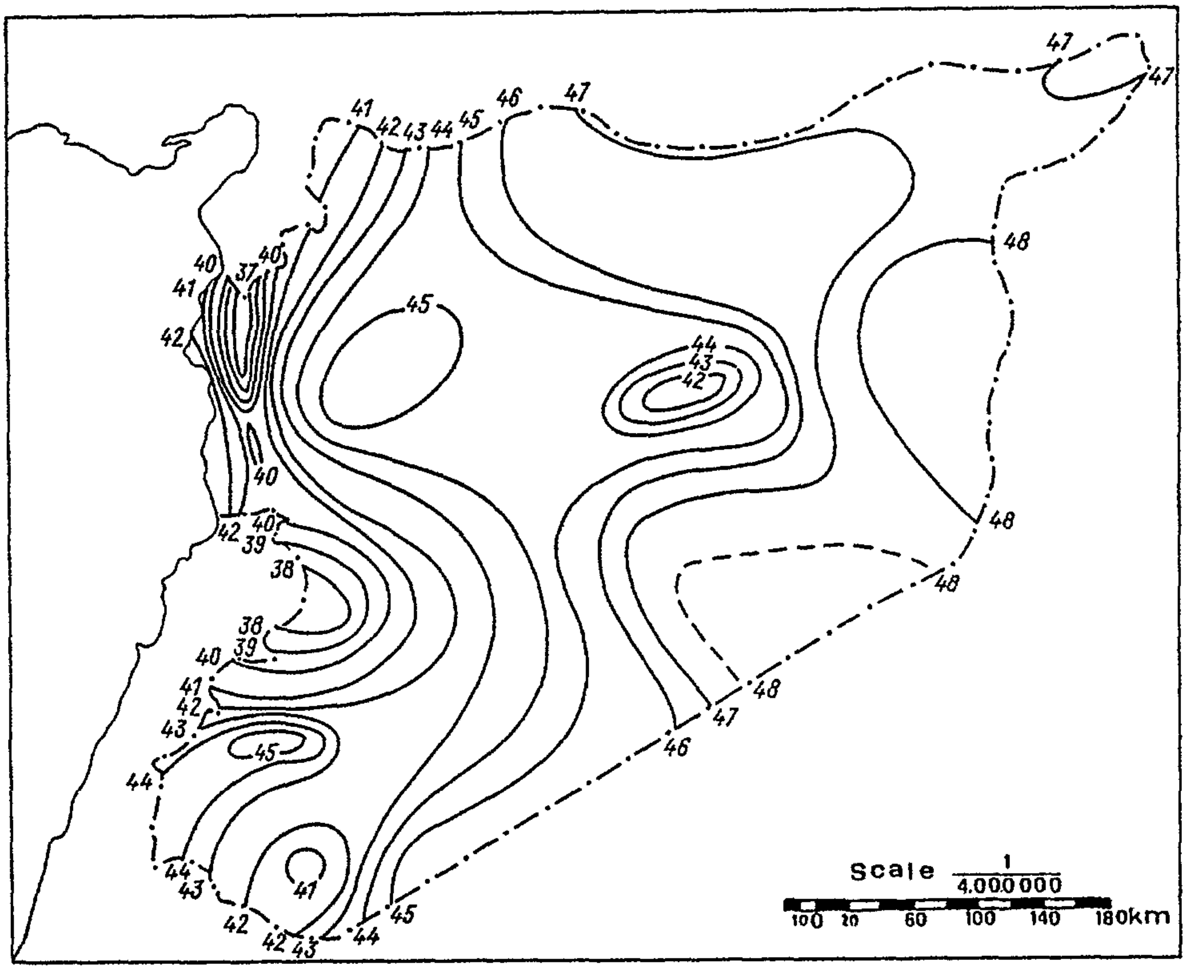

Figure 11 - Isotherms of annual absolute maximum temperature (° C) for the period 1955 to 1984

TABLE 7

Mean minimum monthly and mean minimum annual temperature (° C) for the period 1955 to 1984

	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec	Annual
Coastal Montane Stations													
Kassab	3.4	4.2	7.0	1 0	13.1	16.0	17.7	18.3	17.1	14.3	10.1	5.3	11.4
Sheikh Bader	5.4	6.3	7.9	10.6	13.4	16.5	18.8	19.2	17.3	14.5	11.0	7.0	12.3
Qadmous	3.1	3.6	6.0	9.2	13.0	15.7	17.4	17.9	16.6	14.1	10.2	5.4	11.0
Qastal Ma'af	5.3	6.3	8.4	11.3	14.5	17.8	19.9	20.5	18.8	15.0	12.0	7.2	13.1
Safita	6.6	7.1	9.5	12.6	15.8	18.8	20.8	21 5	20.1	17 5	13 8	8.8	14.4
Jabit Burghal	2.9	3 6	5.8	8.5	11.4	14.4	16.0	16 5	15.3	12.6	9.3	4 6	10.1
Slenfeh	1.4	1.6	4.1	7.5	10.8	14.1	16.0	16.8	14.6	12.1	7.9	3.6	9.2
Coastal plains Stations													
Mina Al Baida	8 2	8 8	10.2	12.7	15.4	19.2	22.2	22.9	20.5	17.1	13.1	9.8	15.0
Lattakia	8.6	9.1	11.0	14.6	17.0	20.1	23.7	24.2	21.9	18.1	13.7	10.0	16.0
Jableh	6.9	7.4	9.1	11.3	14 0	17.3	20.1	20 7	19 1	13.1	12.2	8.8	13.5
Tartous	8.4	8.9	10.5	12.8	15.6	19.1	22.0	22.6	20.4	16 8	13.5	10.0	15 0
El Seen	8.4	8 9	10.5	13.0	15.6	18.9	21.5	22.4	20.4	17.0	13.4	10.0	15.0
Banias	9.7	10.2	11.2	13.5	15.4	19.9	22.5	23.2	22.3	18.9	15.1	11.2	16 1

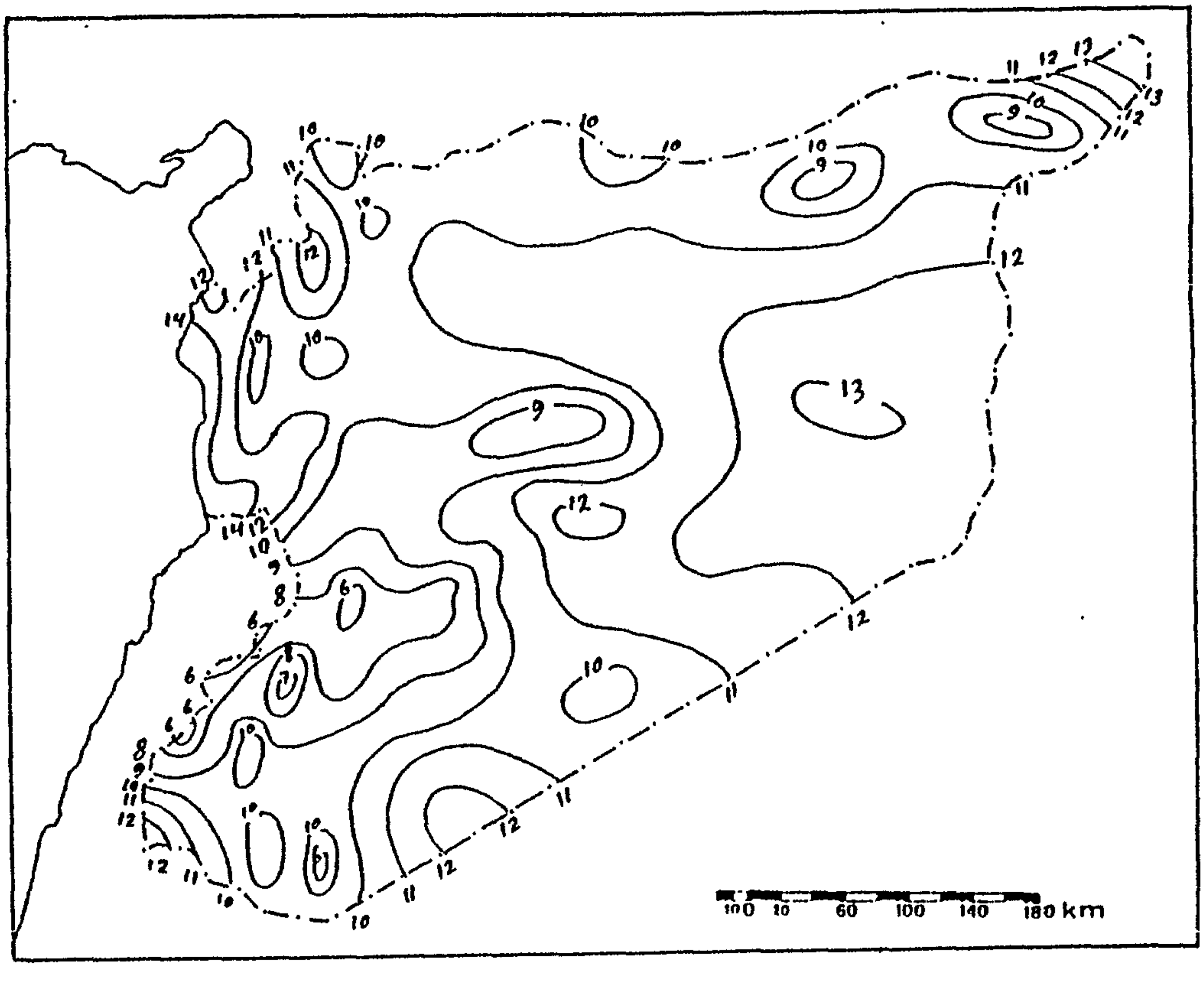

Figure 12 - Isotherms of mean minimum annual temperature (° C) for the period 1955 to 1984

TABLE 8

Absolute minimum monthly and absolute minimum annual temperature (° C) for the period 1955 to 1984

	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec	Annual
Coastal Montane Stations													
Kassab	-7 0	-6 0	-1.8	1.0	7.0	10.5	14.5	14.5	9.0	5.0	0.0	-3.5	-7.0
Sheikh Bader	-5 0	-4.8	0.6	3.0	6.0	11.2	14.0	15.0	10.8	6.8	0.0	-1.5	-5.0
Qadmous	-8.4	-6.1	-3.0	-0.9	5.1	6.8	10.0	12 0	9.1	3.8	-2.0	-4.3	-8.4
Qastal Ma'af	-3 6	-2.4	0.1	2.5	7.4	11.7	16.5	15.8	11.0	7.8	2.3	-1.0	-3.6
Safita	-3.7	-7 7	-0.3	3 4	9.4	12.5	16.6	16.1	15.3	9.5	2.5	-0.8	-7.7
Jabit Burghal	-9.1	-7.7	-2.6	-1.5	3.0	9.5	10.9	12.8	9 0	5.0	-1.5	-4 5	-9.1
Slenfeh	-11.0	-8 8	-4 5	-3.0	5.3	7.5	10.0	12.0	8.5	2.5	-3.0	-7.0	-11.0
Coastal plains Stations													
Mina Al Baida	-3.1	-0.2	1.0	5 0	9.4	10.6	17.4	17 3	14.6	9.0	2.5	0.8	-3.1
Lattakia	-0.1	-0.3	-0.6	7.8	11.0	19.2	19.5	18.7	15.6	10.4	3.4	2.0	-0.6
Jableh	-2.4	-1.5	-2.5	0.5	8.0	12.2	16.0	14.2	12.6	7.5	3.5	-0.2	-2.5
Tartous	-1.0	0.3	1.3	2.3	9.5	13.5	16.7	16.8	14.6	8.0	1.0	1.0	-1.0
El Seen	-2.0	-2.6	1.6	5.0	10.0	13.5	16.8	15.2	14.5	9.5	3.0	0.0	-2.0
Banias	-3.0	3.5	2.5	6 5	11.0	13.5	9.0	20.0	15.3	12.5	5.2	3.6	-3.0

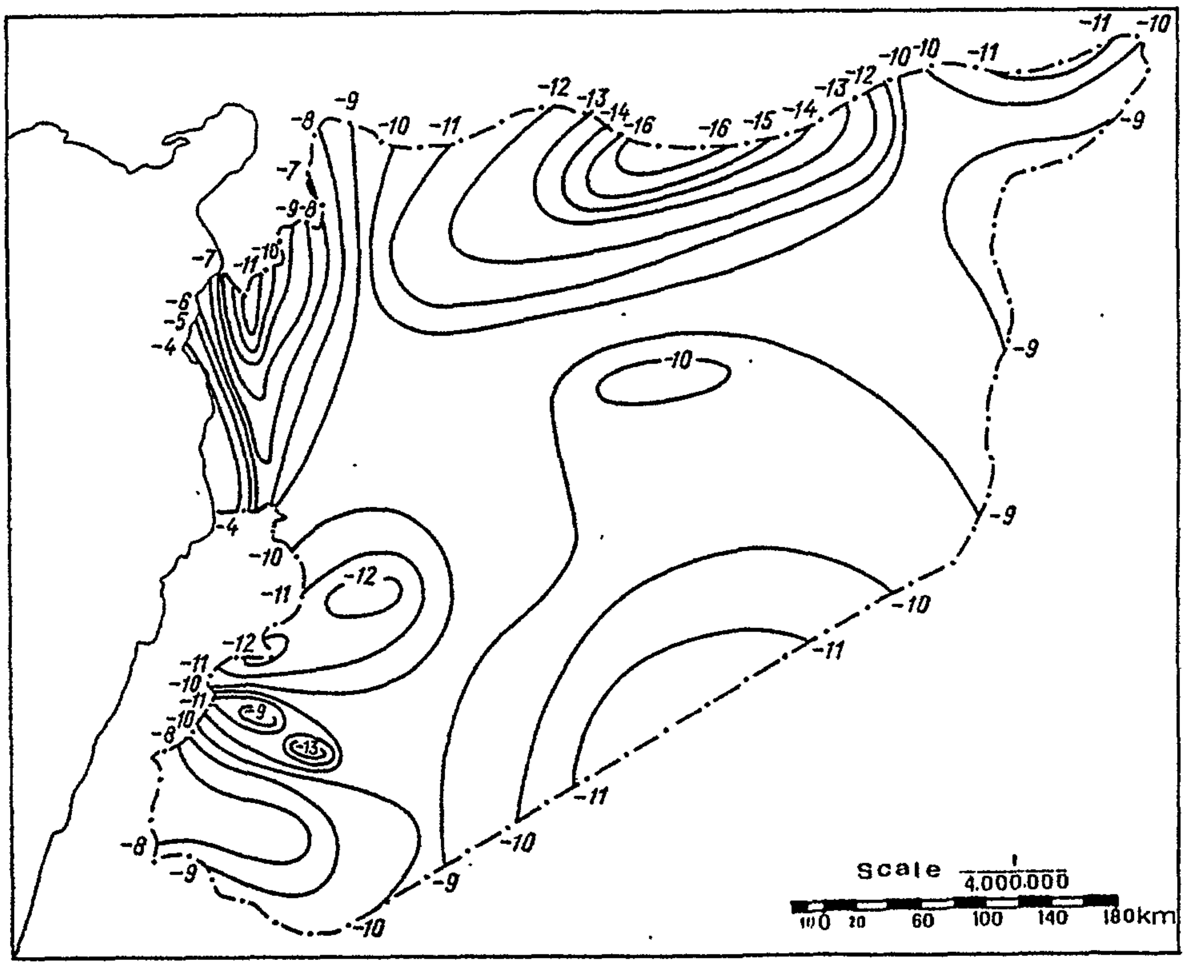

Figure 13 - Isotherms of annual absolute minimum temperature (° C) for the period 1955 to 1984

2.1.4. Relative humidity

In the coastal area relative humidity is high in summer, reaching 80%, and becoming troublesome during hot days in the plains. The mean annual relative humidity in the coastal area is between 66 and 72% (Table 9 and Figure 14).

2.1.5. Potential evapotranspiration

The annual average potential evapotranspiration is high: 1600 mm in the lowlands. It is less (1200 mm) in the mountains. Evaporation in the coastal plains is about 1300 mm on the basis of Penman Relationships (Figure 15).

2.1.6. Winds

Wind fields depend on the distribution of the pressure gradients over the area, as modified by the local topography (Figure 16). Northeasterly to easterly winds prevail over the coastline in winter while southwesterly to southerly winds are dominant in the other seasons. The annual prevailing wind direction on the coastal plain is southerly; westerly over the mountains (Figure 16).

In addition to the prevailing winds, northerly or easterly winds blow over the area during spring and autumn. Unlike the westerly wet wind, the northerly wind is dry and cold.

The annual average wind speed is about 4 m sec^{-1}; the average wind speed in winter is about 5.8 m sec^{-1}, in summer 6.5 m sec^{-1}. The maximum recorded wind speed was 27 m sec^{-1}.

The most dangerous winds are the stormy, very dry and cold easterly winds, which may cause serious damage to natural vegetation and some crops. There are around 4-8 stormy days a year in the coastal plains; 5-16 days in the mountains.

Thunderstorms and lightening are a common occurrence with an average of 40 days with thunderstorms a year. Spring hail seriously damages fruit and vegetable orchards, throughout the coastal region but particularly in the hills. The effects of frost are known in the higher parts above 300-500 m, but also occasionally occur in the plains.

From an environmental viewpoint the region may be divided into different agroclimatic and bioclimatic subregions. According to Emberger's formula there are only two bioclimatic areas: Humid and Semi-humid (Figure 17). Ahdaly's classification (1979) shows small upland areas of "dense forest" agroclimate, irrigation areas of "fruit trees and vegetable" on the hills and coastal plains.

To conclude, the climate of the coastal region of Syria is a subtype of the Mediterranean climate, with coastal and montane sub-types, characterized by alternation between a rainy, relatively cool winter season, and a dry, warm season.

TABLE 9

Mean monthly and annual relative humidity (%) for the period 1955 to 1984

	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec	Annual
Coastal Montane Stations													
Kassab	75	73	67	64	62	62	70	70	66	61	64	74	67
Sheikh Bader	74	73	71	70	56	66	72	73	70	65	66	74	69
Qadmous	75	74	70	64	61	61	68	68	65	61	58	71	66
Qastal Ma'af	74	73	7	71	70	71	77	77	73	66	64	73	72
Safita	73	68	66	66	65	67	73	73	68	61	58	67	67
Jabit Burghal	77	74	70	65	65	64	67	68	65	63	67	73	68
Slenfeh	81	78	74	67	64	63	66	66	64	61	65	77	69
Coastal plains Stations													
Mina Al Baida	68	67	68	73	73	73	74	73	71	67	64	67	70
Lattakia	64	62	64	67	72	74	74	71	68	64	56	63	67
Jableh	72	68	69	70	72	73	73	71	68	66	67	67	70
Tartous	67	64	67	68	70	72	74	73	69	66	61	65	68
El Seen	69	67	68	67	70	70	73	73	71	69	68	67	69
Banias													

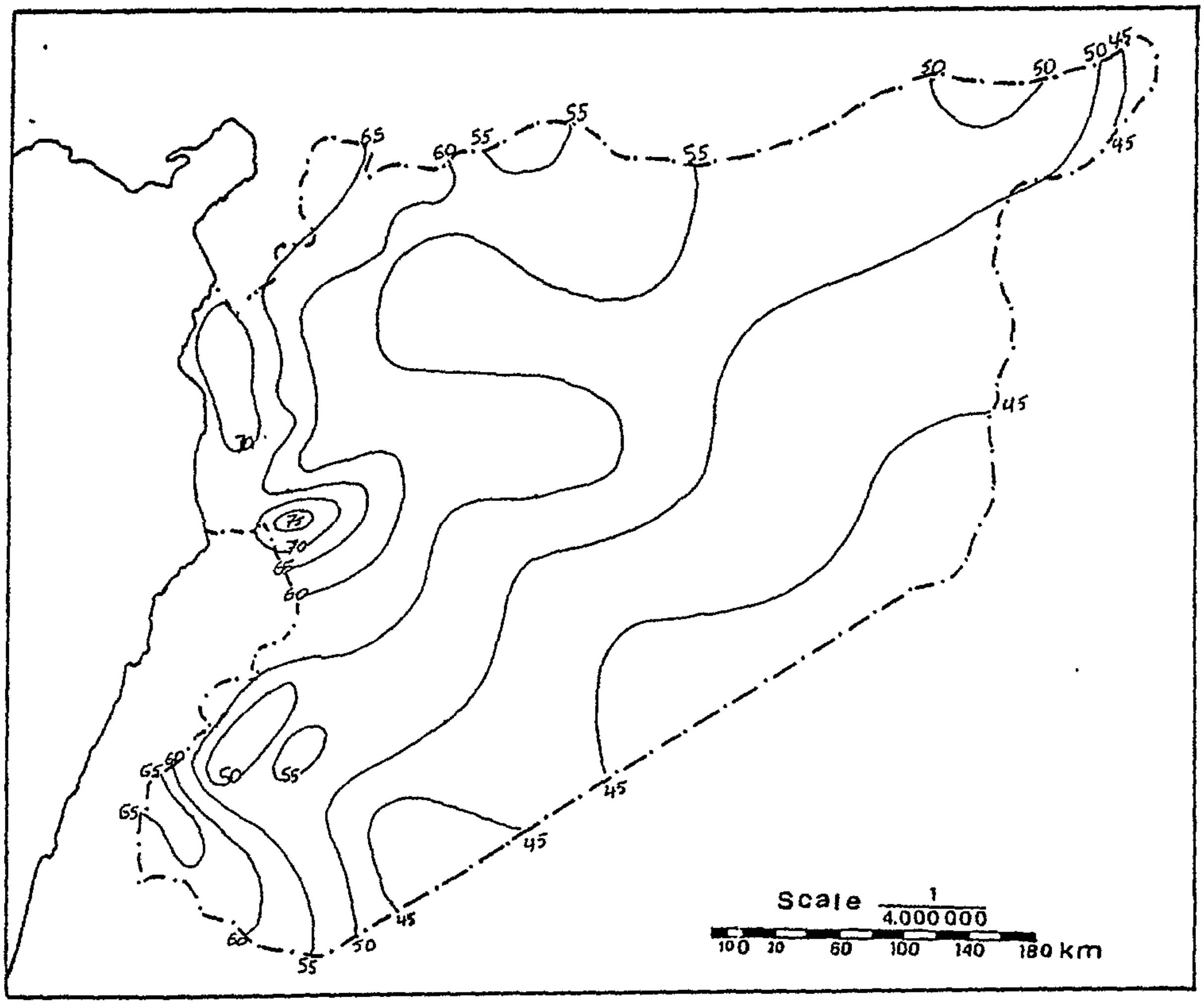

Figure 14 - Mean annual relative humidity (%) for the period 1955 to 1984

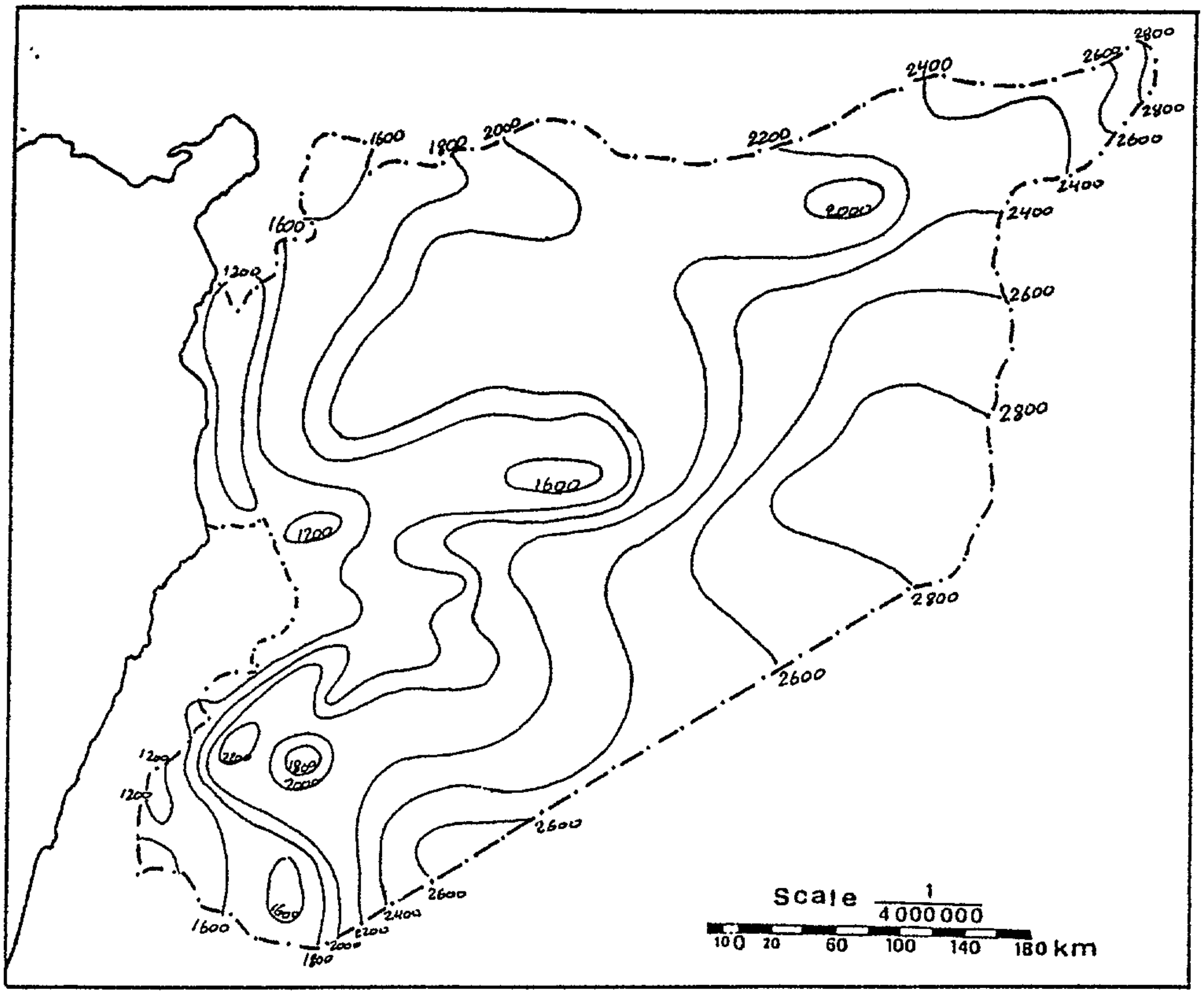

Figure 15 - Mean annual potential evaporation (mm) for the period, 1955 to 1984

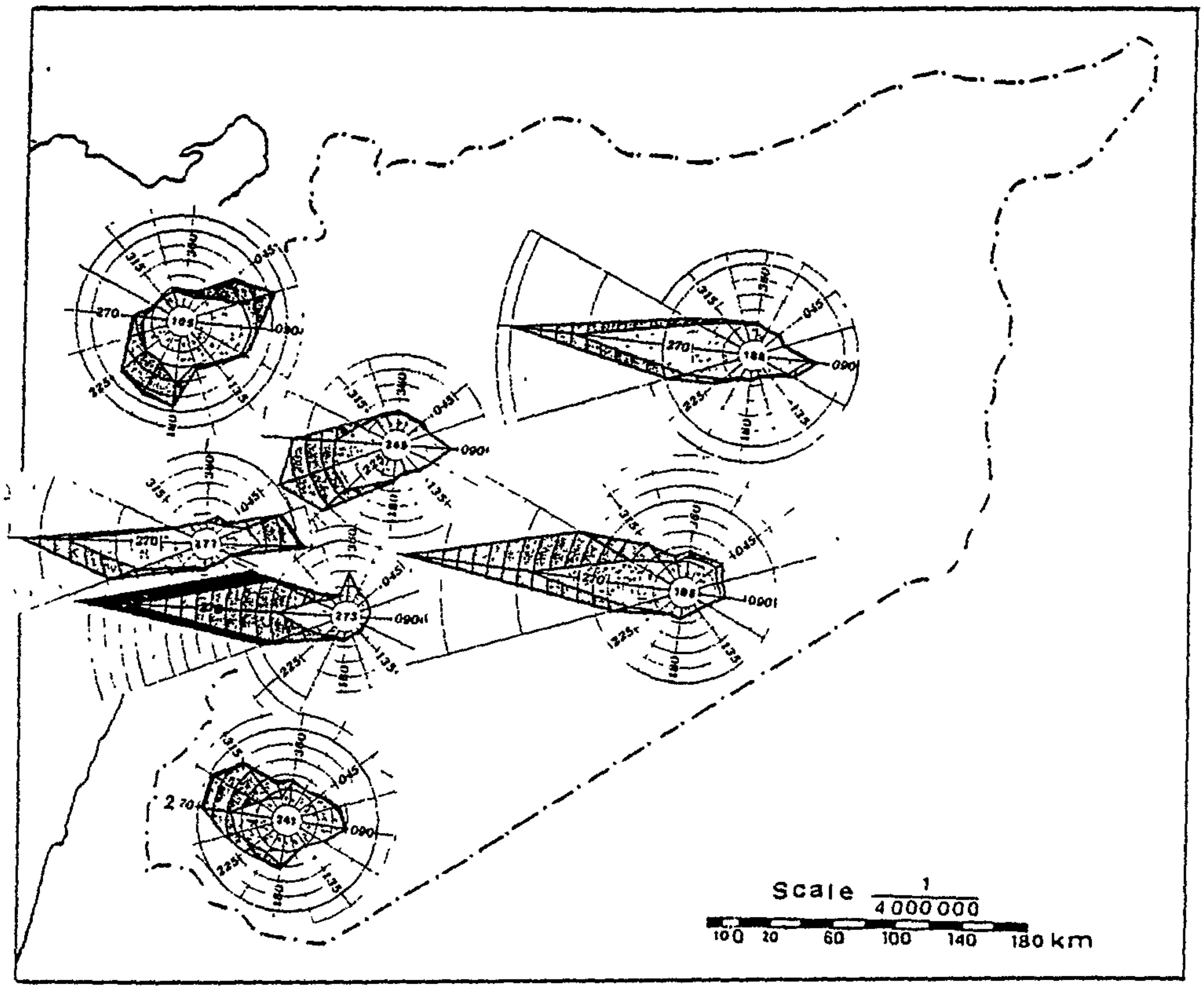

Figure 16 - Annual wind roses based on data for seven stations

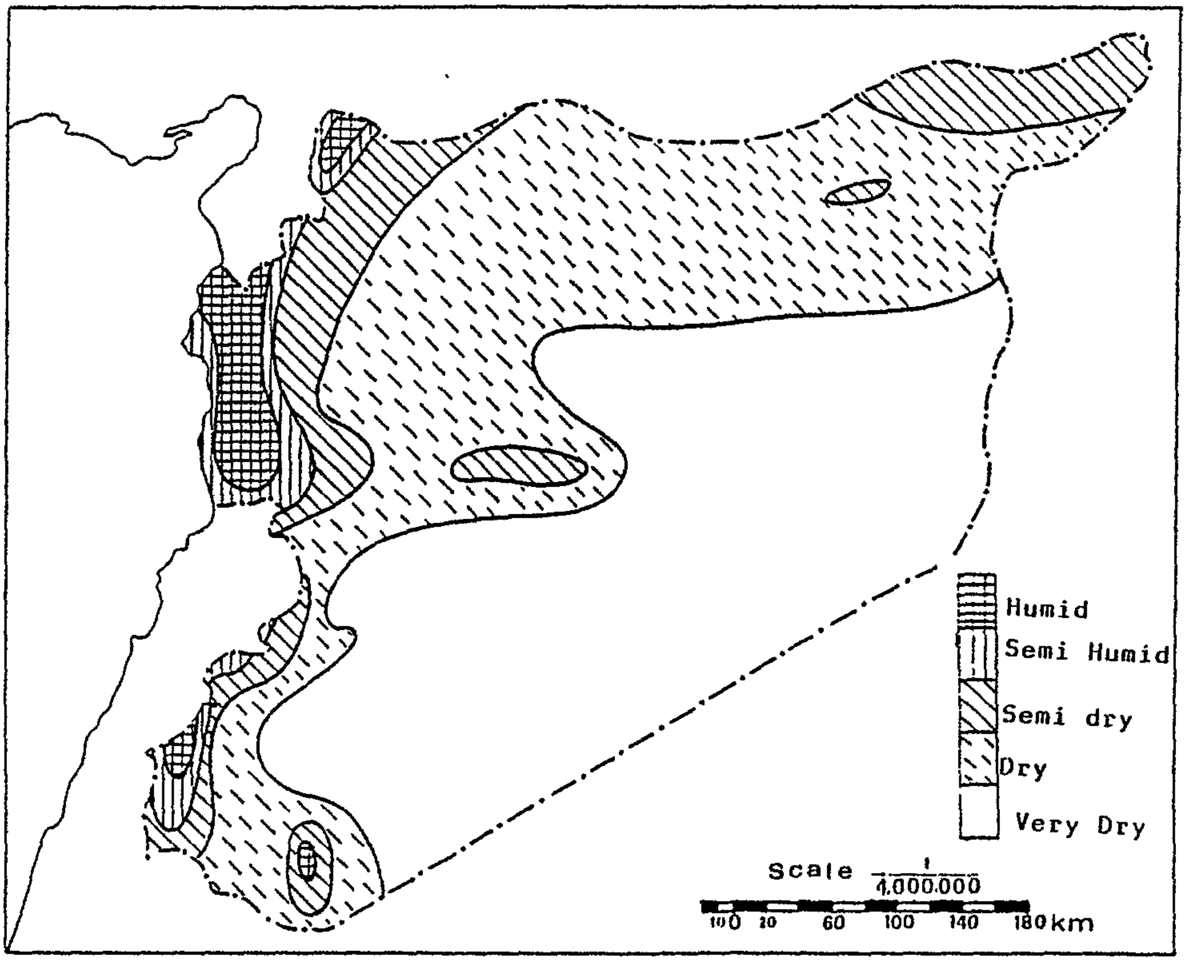

Figure 17 - Bioclimatic regimes in Syria based on Emberger's formula using data for the period 1955 to 1984

2.1.7. The implications of global warming for the regional climate

2.1.7.1 General circulation

In order to understand the nature of the response of the Mediterranean climate to global greenhouse gas forcing it is necessary to analyse the possible changes in the general circulation, that might occur in the next century.

It is currently believed that the rate of increase of global mean temperature could be about 0.3 °C per decade (with an uncertainty range of 0.2 °C to 0.5 °C per decade). Therefore, the elevation of global mean temperature could reach: +1.2 °C by 2030; +1.8 °C by 2050 and as much as +3 °C by 2100.

During this global warming, the equator-pole temperature difference will decrease, leading to changes in the atmospheric pressure field and atmospheric general circulation. It might be suggested that with a comparatively small warming, the subtropical high-pressure belt in the northern hemisphere will extend northwards (Report of the Conference on Climate and Water - 1989 - page 20). The likely general northward shift of the atmospheric circulation pattern will influence the path and frequency of passage of mid-latitude cyclones over middle and eastern parts of the Mediterranean region (Wigley, 1992).

Such shifts could result in a decrease in the movement of cyclones from the Atlantic Ocean to the Mediterranean, but increase the generation of cyclones over the eastern Mediterranean, resulting from the temperature contrast between European cold air, and the Mediterranean relatively warm water. The increased flow of cold air over the Mediterranean could counter the increase in temperature in the eastern parts of the region during winter, and could increase the winter rainfall. The passage of the Khameseen cyclones, derived from Saharan North Africa, could shift northward over the eastern parts of the Mediterranean. As the warm, dry air, characteristic of these winds moves over the sea surface it picks up moisture hence an increased frequency of this wind type could mean an increase in spring rainfall over the eastern Mediterranean.

The Indian monsoon low pressure, which influences the eastern coast of the Mediterranean occasionally during summer and autumn periods (Wigley and Farmer, 1982) could extend further north. If this were to occur then it would provoke the descent of cold air from northeastern Asia to the northeastern part of the Mediterranean, resulting in some days in summer with lower temperatures but very dry air (may be 15 °C during autumn). This could lengthen the dry season and increase the range between temperature maxima and minima during that period.

In view of these considerations, and the results of the climatic change integrated modelling carried out by the Climatic Research Unit of the University of East Anglia (Climatic Research Unit, 1992), the changes that could occur during the next century, can be summarized as follows.

2.1.7.2 Precipitation changes

The scenarios of precipitation are shown in Figures 18, and 19 and in Table 1 (Operative scenarios for Syria). The amount of annual rainfall could decrease by:

- 0 to -3.6% by 2030, 0 to -6% by 2050 and 0 to -10% by the year 2100.

Winter rainfall could increase by:

- +3.5% to +10.8% in the plains, 0 to +3.6% in the mountains by the year 2030;
- +3% to +12% in the plains, 0 to +6% in the mountains by 2050; and
- +4% to +20% in the plains and 0% to +10% in the mountains by 2100.

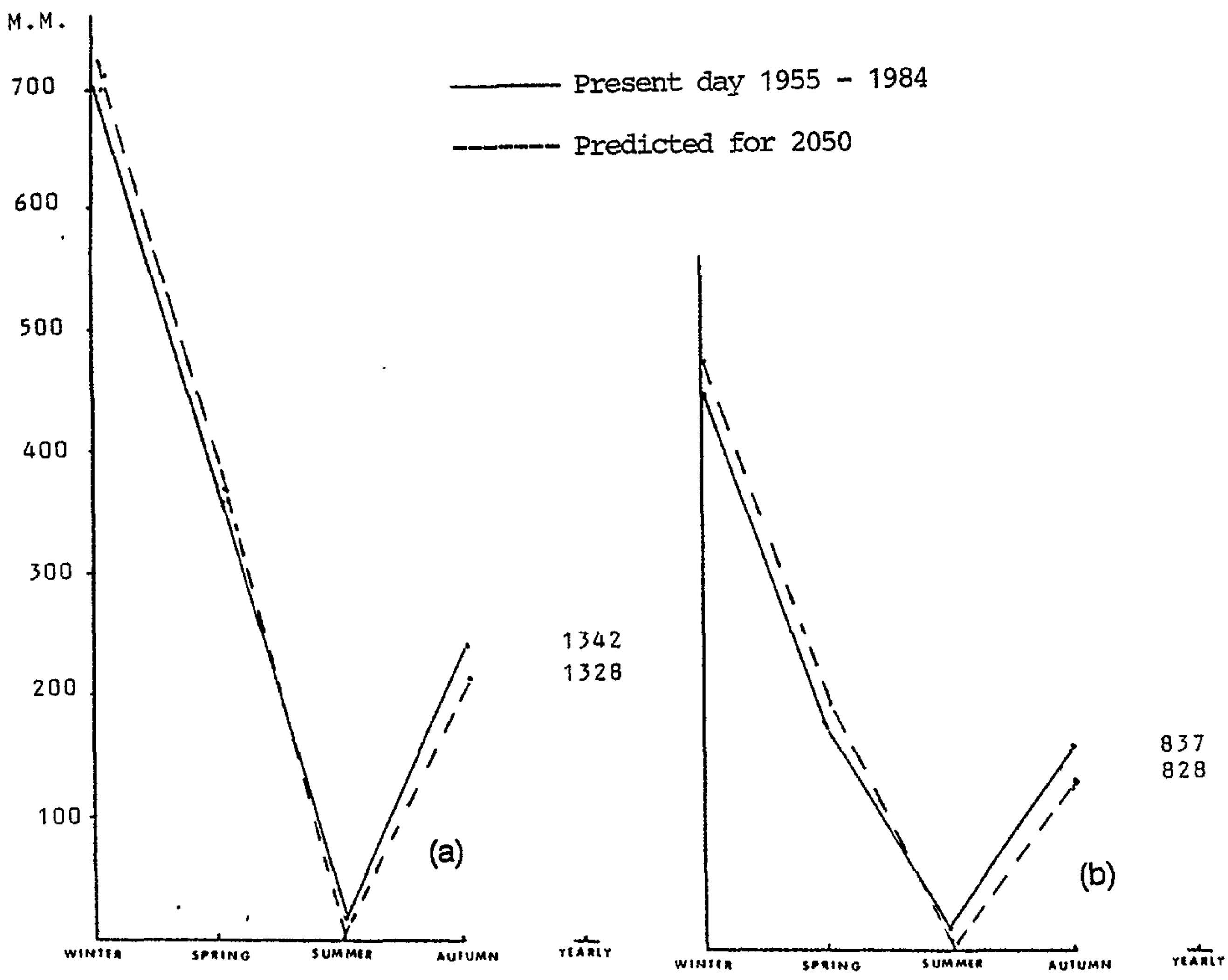

Figure 18 - Scenarios of changes in precipitation in the Syrian coastal region (a) Coastal mountains and (b) Coastal plains

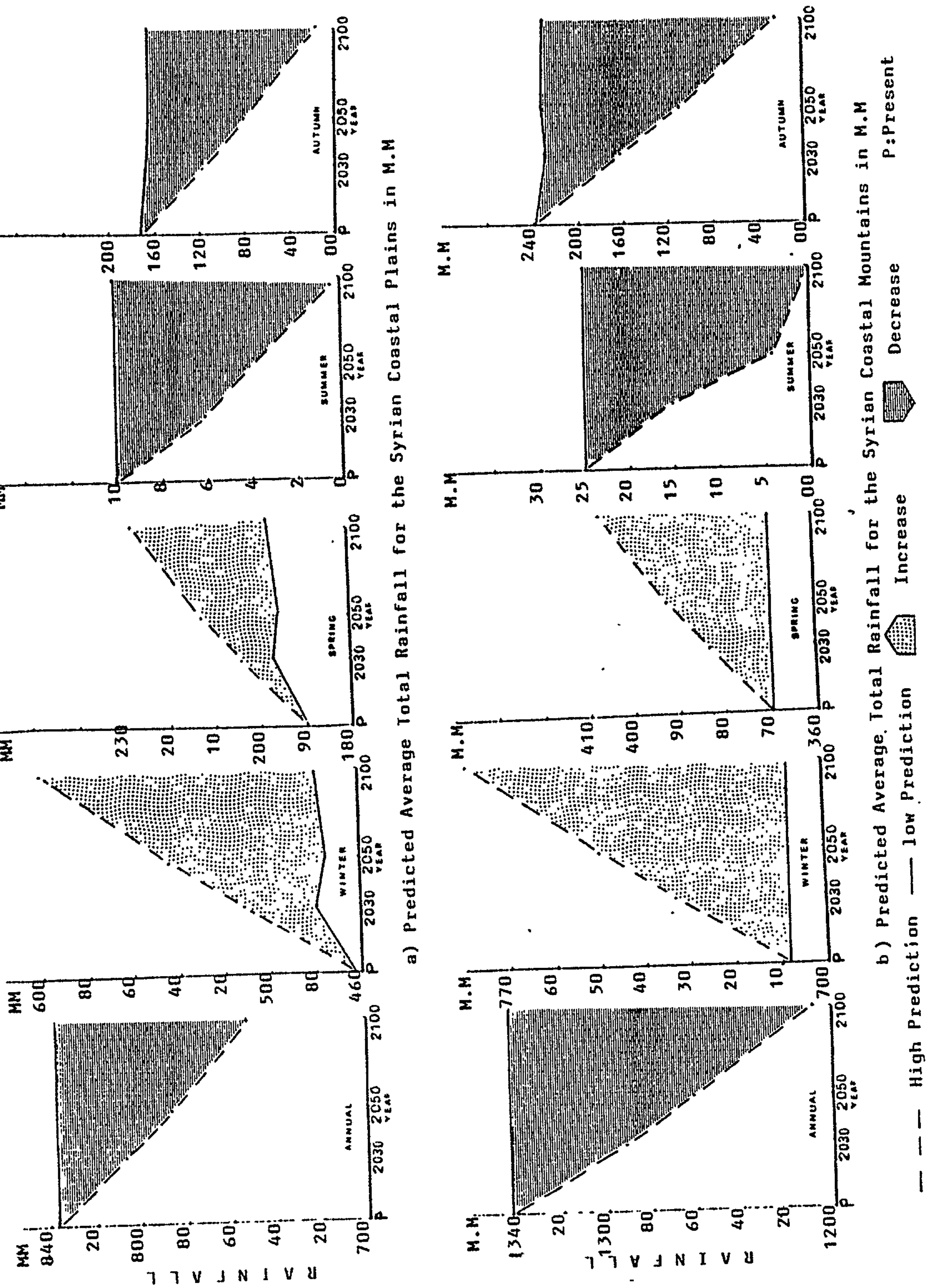

Figure 19 - Predicted average total rainfall in mm, under high and low scenarios of change for (a) Syrian coastal plains and (b) Syrian coastal mountains

Spring rainfall could increase by:

- +3.6% to 7.2% in the plains and 0% to +3.6% in the mountains by the year 2030;
- +3% to +12% in the plains, and 0% to +6% in the mountains by the year 2050; and,
- +4% to +20% in plains and 0% to +10% in the mountains by 2100.

Summer rainfall is predicted to decrease in general by:

- 0% to -39.6% by the year 2030, 0% to -66% by the year 2050, and 0% to -110% by the year 2100. The unrealistic nature of these calculations should be noted since summer rain, is absent in most years and in some years only amounts to 1-2% of the annual total.

Autumn rainfall is also predicted to decrease by

- -3.6% to -32.4% by the year 2030, by -3% to -54% by the year 2050 and -4% to -90% by the year 2100, so that the dry period could be longer than at present.

The general conclusion, based on the operative scenarios, is that winter and spring rainfall could increase appreciably while in contrast precipitation in autumn and in summer would decrease. The wide range of uncertainty in these predictions (Figure 19) should be noted, as well as the unrealistic nature of some of the conclusions of the scenarios: for example that winter and spring rainfall should increase less in the mountains than in the coastal zone; that in regard to the overall yearly decrease in precipitation, the strong apparent summer-autumn decrease cannot outweigh the winter increase, since summer rain only occurs in some years and amounts to only 1-2% of the total. As stated by the Climatic Research Unit (1992), the confidence level of rainfall predictions is still low.

2.1.7.3 Temperature change

The scenarios for temperature changes are shown in Table 1 and in Figures 20, 21, 22 and 23 for the annual average of the surface air temperature. The scenarios suggest that:

Annual average temperature will increase by:

- +1.44 °C to +2.16 °C in the plains and +1.8 °C to +2.88 °C in the mountains, by the year 2030;
- +1.2 °C to +3.6 °C in the plains, and +1.5 °C to +4.8 °C in the mountains by the year 2050; and
- +1.6 °C to +6 °C in the plains, and by +2.0 °C to +8.0 °C in the mountains by the year 2100;

Winter average temperature could increase by:

- +1.8 °C to +2.16 °C by the year 2030;
- +1.5 °C to +3.6 °C by the year 2050; and
- +2.0 °C to +6.0 °C by the year 2100;

Spring average temperature could increase by:

- +1.44 °C to +1.8 °C in plains and +1.8 °C to +2.16 °C in mountains by the year 2030;
- +1.2 °C to +3.0 °C in plains, and +1.5 °C to +3.6 °C in mountains by the year 2050; and
- +1.6 °C to +5 °C in plains, and +2.0 °C to +6.0 °C in mountains by the year 2100;

Summer average temperature may rise by:

- +1.98 °C to +2.16 °C in the plains and +2.16 °C to +2.88 °C in the mountains by the year 2030;
- +1.65 °C to +3.6 °C in the plains and +1.8 °C to +4.8 °C in the mountains by the year 2050; and
- + 2.2 °C to +6.0 °C in the plains and +2.4 °C to +8.0 °C in the mountains by the year 2100;

Autumn average temperature could be:

- +1.8 °C to +2.16 °C in plains and +2.16 °C to +2.52 °C in mountains by the year 2030;
- +1.5 °C to +3.6 °C in plains and +1.8 °C to +4.2 °C in mountains by the year 2050; and
- +2.0 °C to +6.0 °C in plains and +2.4 °C to +7.0 °C in mountains by the year 2100.

In conclusion, the scenarios suggest an increase in mean temperature of between 0.8 and 1.2 °C per degree of global change in the lowland areas and of between 1.0 and 1.6 °C per degree of global change in the mountain, by the year 2030. The increase in summer and autumn is greater than that expected in winter and spring. The range between the suggested extreme values may be larger than that for the present day, suggesting that absolute maxima may be higher and absolute minima lower than at present.

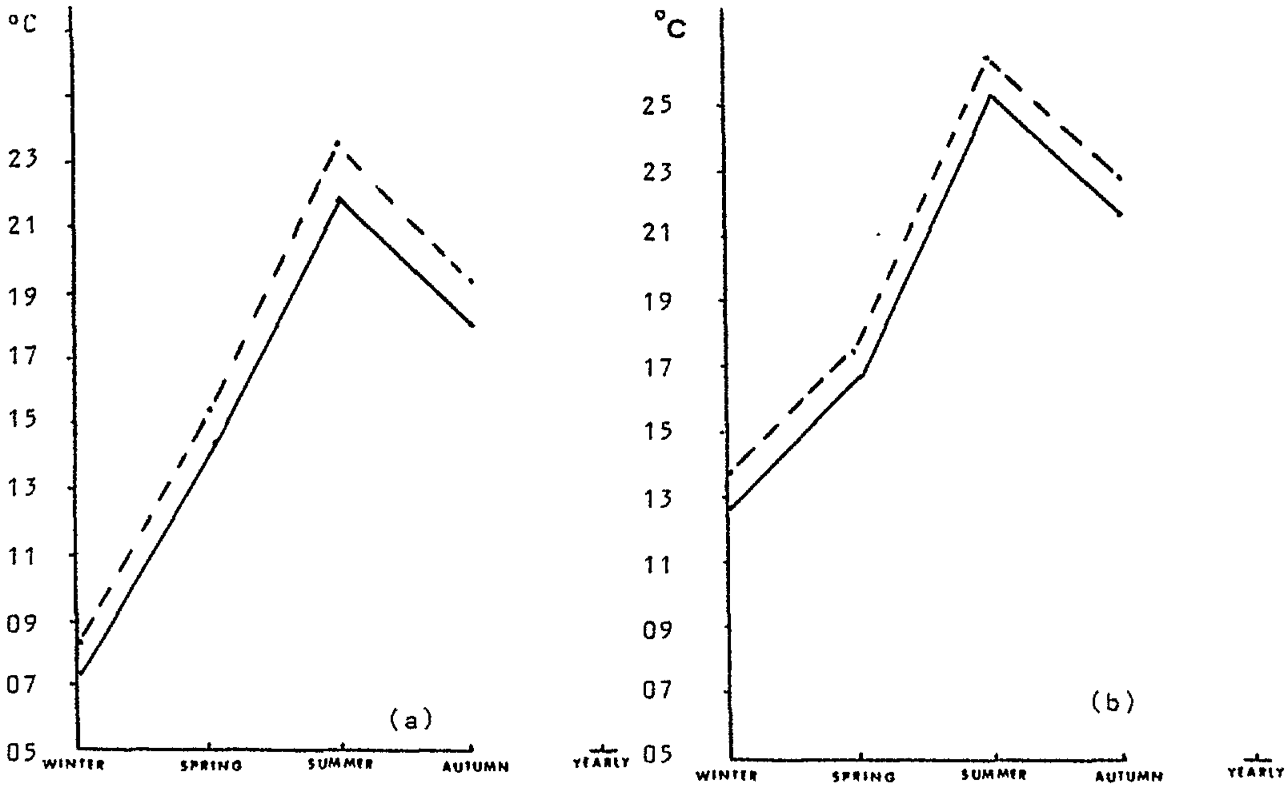

Figure 20 - Suggested average temperature change by the year 2050 in (a) coastal mountains and (b) coastal plains, compared with present temperatures based on data for the period from 1955 to 1984

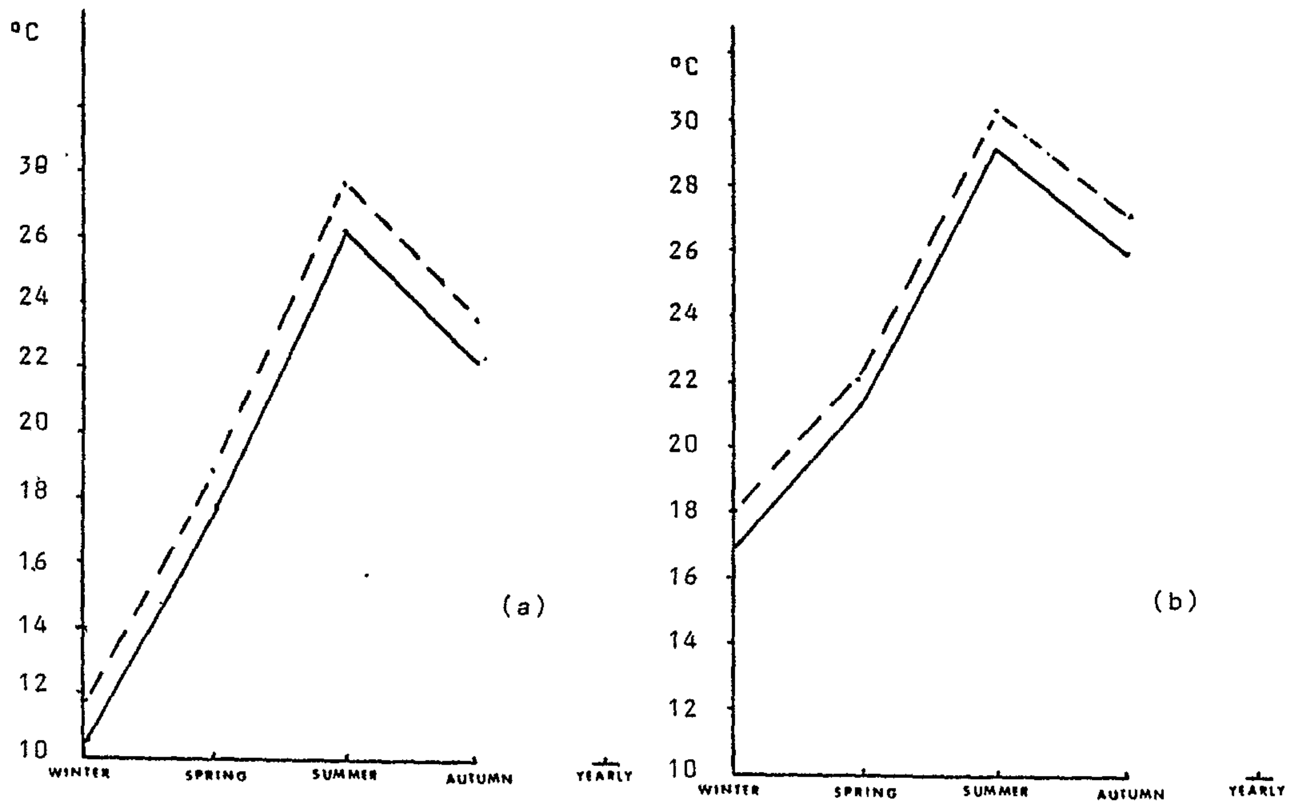

Figure 21 - Suggested changes to maximum temperature by the year 2050 in (a) coastal mountains and (b) coastal plains compared with present temperatures based on data for the period 1955 to 1984

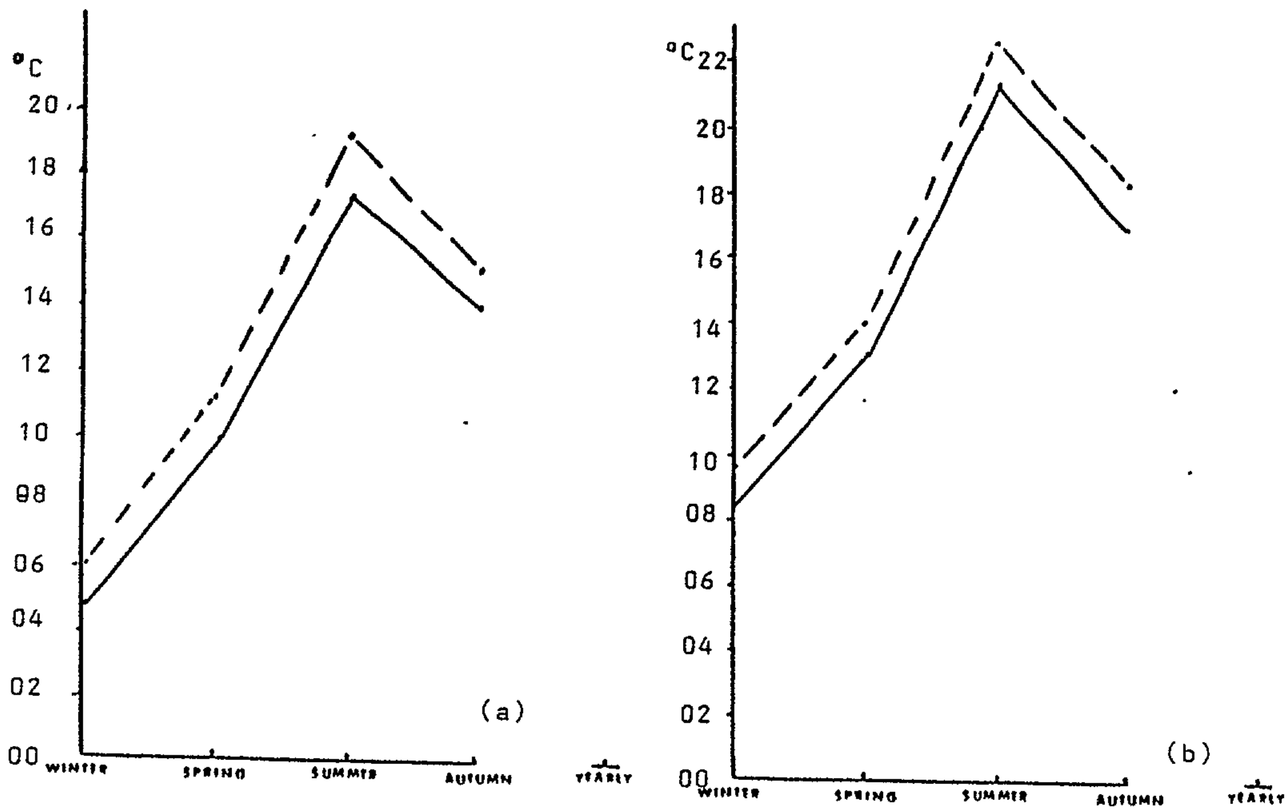

Figure 22 - Suggested changes in minimum temperature by the year 2050 in (a) coastal mountains and (b) coastal plains, compared with present temperatures based on data for the period 1955 to 1984

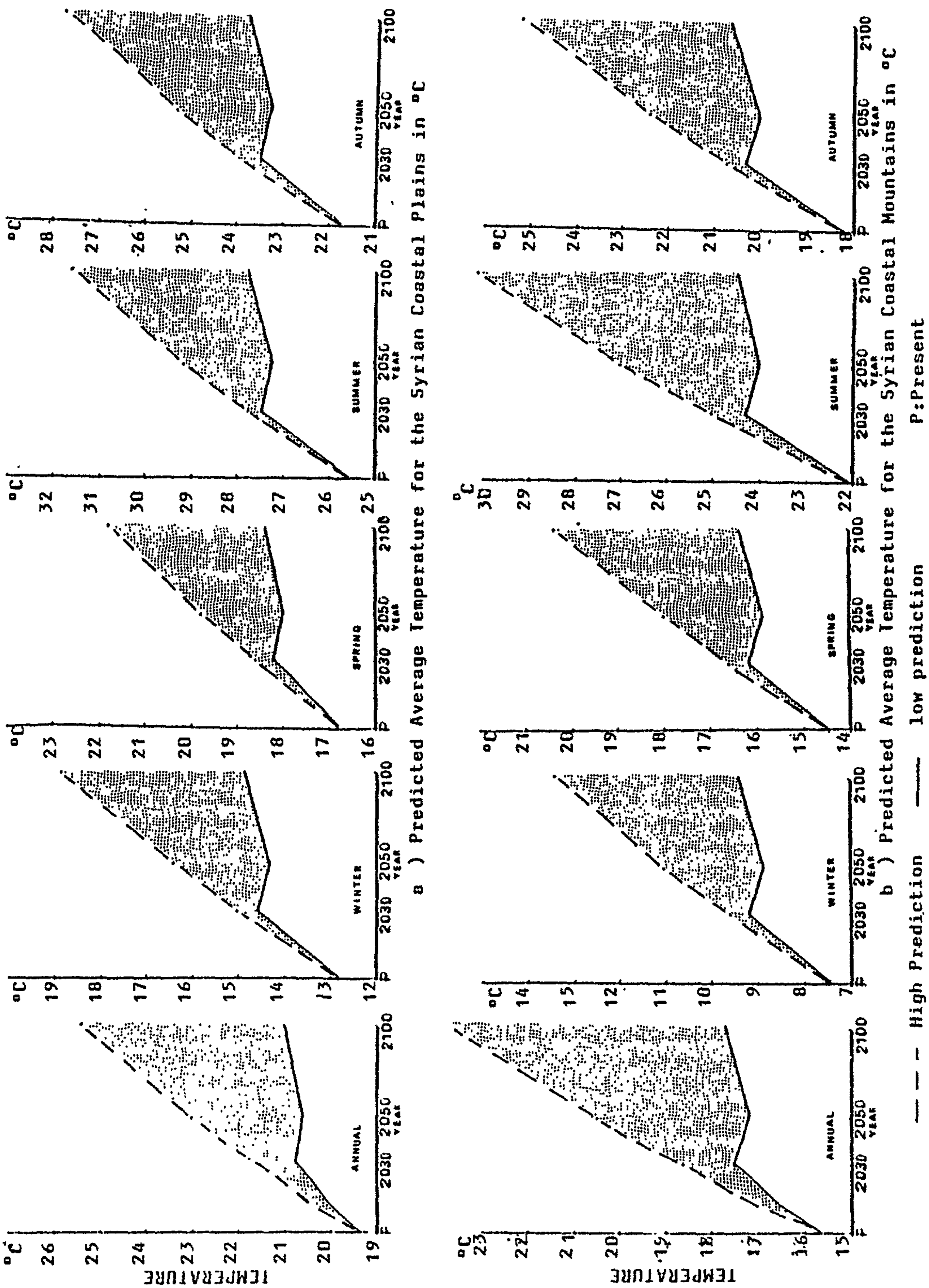

Figure 23 - Suggested changes in average seasonal temperature (°C) to the year 2100 in (a) Syrian coastal plains and (b) Syrian coastal mountains compared with present temperatures based on data for the period 1955 to 1984

2.1.7.4 Relative humidity (RH) changes

In general any change in temperature means a probable change in relative humidity. The scenarios of changes to relative humidity are shown in Figures 24 and 25. The annual average RH is likely to increase by between 0% and 2% by the year 2050; and, by 0% to 3% by the year 2100 in the Syrian coastal area.

The scenarios suggest that mean winter RH will rise by between 7% and 9% in lowland areas; and by 12% to 15% in the mountains, by 2030. By 2050 the increase will be around 6% to 13% in lowland areas, 11% to 24% in mountains; and by 2100 7% to 24% in coastal plains, 14 to 35% in montane areas.

Spring average RH is predicted to increase by between 4% and 6% in the coastal plains; 6% to 8% in the mountains, by the year 2030. By the year 2050 the increase will be around 3% to 9% in the lowlands, and 4% to 12% in mountains; and by 2100 the increase could reach between 4% and 14% in coastal plains, 7 to 21% in the mountains.

Summer average of RH is predicted to decrease by the year 2030 by around -4% in coastal plains, and by between -4% and -6% in the mountains. By the year 2050 decreases could reach between -3% and -7% in the coastal plains, -4% to -10%, in the mountains; and by 2100 it could decrease by -4% to -11% in coastal plains, and by -6% to -17% in the mountains.

Autumn average of RH is predicted to decrease by 2030 by -5% in the plains, and by -9% to -11% in the mountains. By the year 2050 the decrease could be between -3% and -8% in coastal plains, -8% to -19% in mountains; and, by the year 2100 -5% to -14% in the coastal plains, and -11% to -31% in mountains.

Overall this suggests that summer and autumn could be both dryer and longer, and this could be very disadvantageous both for agricultural crops and natural vegetation as a consequence of increased water stress.

2.1.7.5 Potential evapotranspiration changes

Under these scenarios of climate change and global warming, evaporation from open water bodies and evapotranspiration losses will increase considerably as a consequence of the following factors:

- the surface air warming;
- the surface water warming;
- the rise in global mean sea level, which means an increase in the surface area of the water; and
- reduced relative humidity during summer and autumn.

The average potential evaporation and evapotranspiration could increase by 8% to 15% by the year 2030; by 10% to 20% by the year 2050; and by 15% to 25% by the year 2100. But the greatest increase is likely to occur during summer and autumn resulting in a decrease in the soil moisture and a greater frequency and severity of drought stress in agricultural crops and natural vegetation, particularly in the upper montane areas.

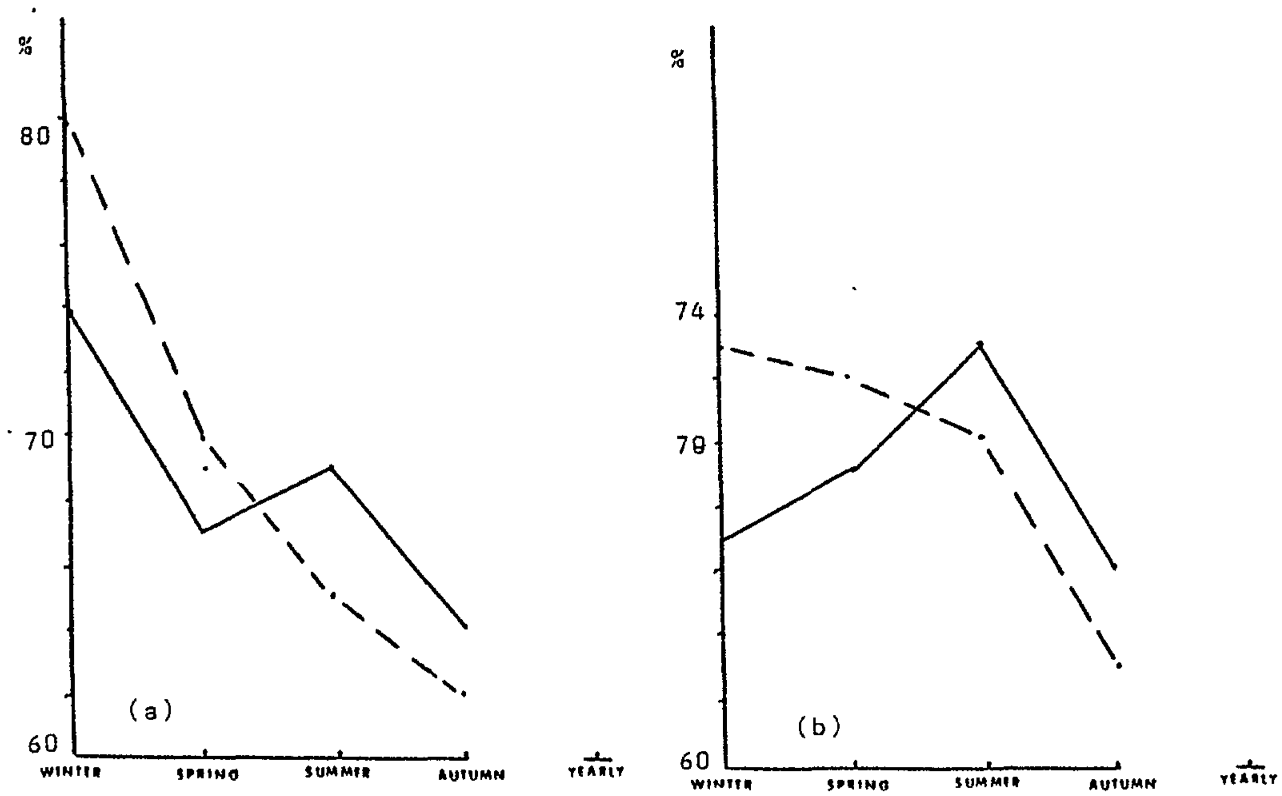

Figure 24 - Suggested changes in average relative humidity (%) by 2050 in (a) coastal mountains and (b) coastal plains, based on data for the period 1955 to 1984

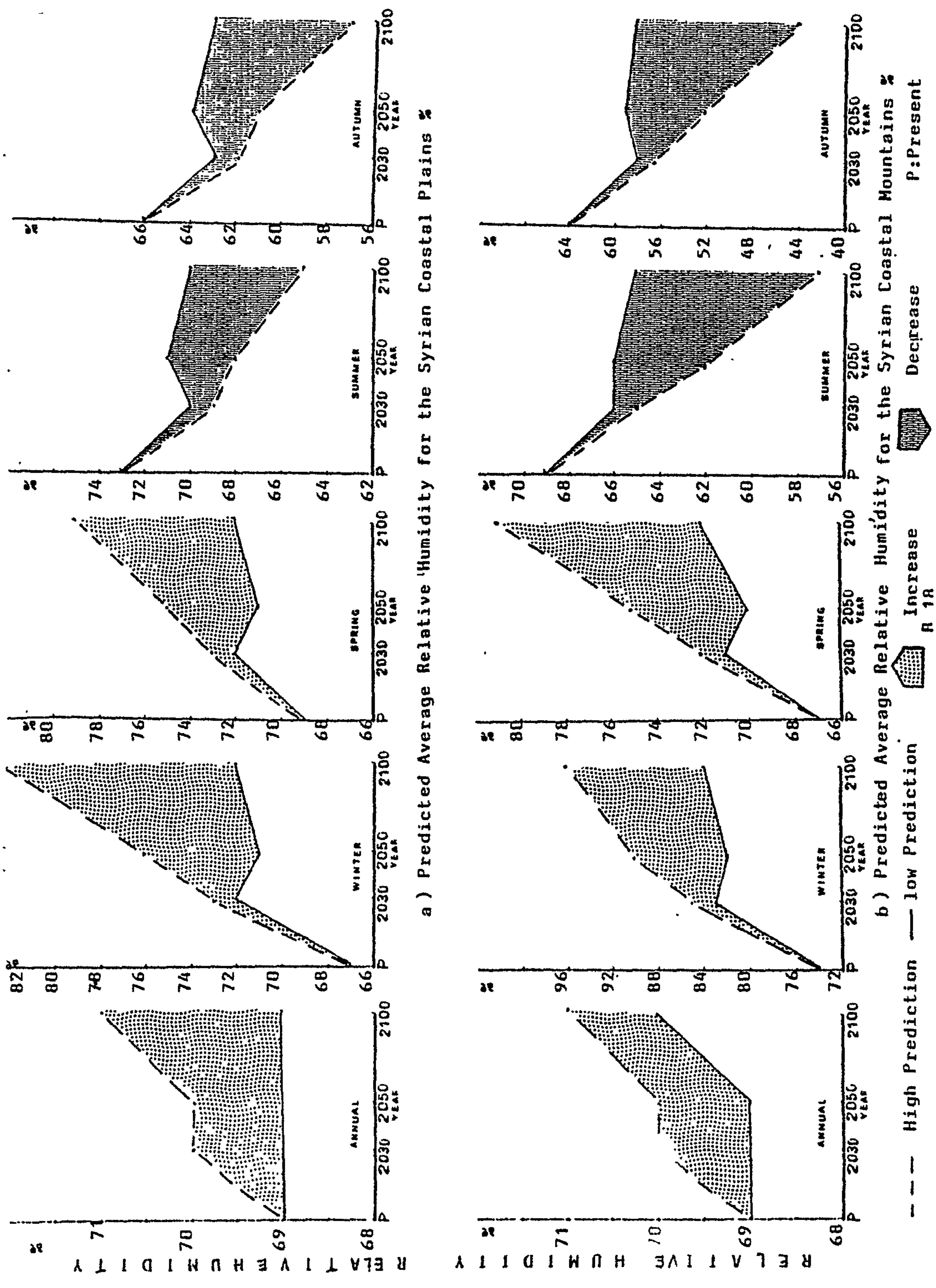

Figure 25 - Suggested seasonal changes in average relative humidity (%) in (a) Syrian coastal plains and (b) Syrian coastal mountains, based on data for the period 1955 to 1984

2.1.7.6 Wind changes

The predictions of general circulation models (GCMs) and in particular the likely changes in atmospheric pressure fields during the next century, are unlikely to result in changes in the prevailing wind direction in this area. This suggests that the prevailing wind directions will remain much as at the present (section 2.1.6). The northerly and northeasterly dry winds, could be colder than at present and could prevail for longer periods during spring and autumn. Due to the increase in temperature contrast between the land and sea surfaces, wind speed could be higher than at present, especially in the case of westerly winds in winter which are associated with the passage of cyclones over the eastern part of the Mediterranean. The stormy and cold easterly winds could also become more intense. The annual average of stormy days, thunderstorms, lightning, spring hail and frost could be higher than at present.

STATIONS	LATITUDE-N	LONGITUDE-E	ALTITUDE (m)	TYPE
KASSAB	35° 56'	36° 59'	730	C
SHEIKH BADER	35° 00'	36° 05'	200	C
QADMOUS	35° 06'	36° 09'	750	
QASTAL MA'AF	35° 49'	35° 57'	657	C
SAFITA	34° 49'	36° 08'	350	S
JABIT BURGHAL	35° 30'	36° 09'	950	C
SLENFEH	35° 36'	36° 11'	1100	C
MINA AL BAIDA	35° 33'	35° 43'	8	S
LATTAKIA	35° 30'	35° 47'	7	S
JABLEH	35° 22'	35° 57'	45	
TARTOUS	34° 53'	35° 53'	15	S
EL SEEN	35° 15'	35° 58'	40	C
BANIAS	33° 15'	35° 41'	5	C

C: Climate station S: Synoptic station

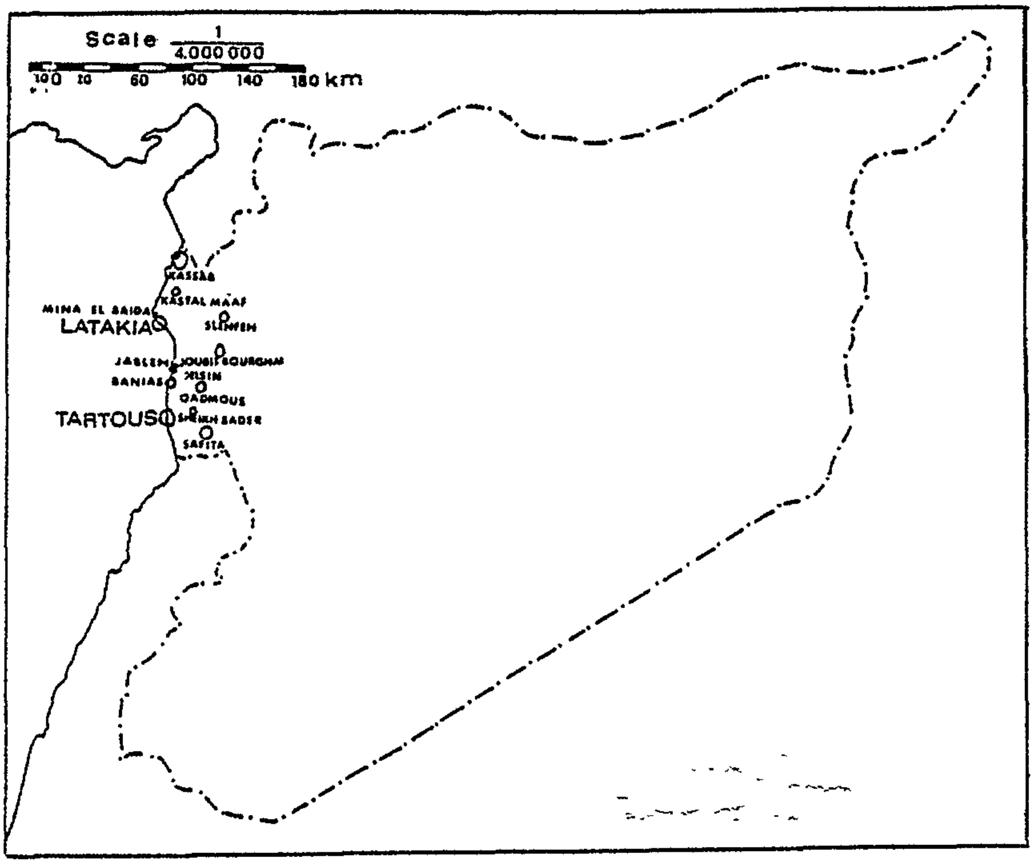

Figure 26 - Location, altitude and type of meteorological station in the Syrian coastal region, from which data have been derived for the analyses described in this section of the report

2.2. Lithosphere

2.2.1. Topography and relief

The coastal region is situated in northwestern Syria by the Mediterranean, and lies between latitudes 34° 35' and 35° 55' North, and longitudes 35° 43' and 36° 20' East. The total area of the region is 5070 km^2. The eastern margin is the crestal divide of the Jebel as Sahel range, the western margin is the Mediterranean shore. To the north and south the limits are respectively the Syrian-Turkish and the Syrian-Lebanese borders. The coastline is only 180 km long, and the 10 km wide coastal zone has a total area of about 1800 km^2.

Topographically, the coastal region can be divided into three longitudinal bands: the coastal plain, the middle zone of plain/hilly country (100-400 m above sea level) and the mountains (400-600 m and higher). Figure 27 shows the general topography with 100, 200, 400, 600, and 1,000 m contour lines.

The main orographic element of the area under study is the Jebel as Sahel chain (or Jebel Saheiligheh), which stretches in a N-S direction from the North Kabir river to the South Kabir valley, for a total of 50 km, at a distance of 20-40 km from the coastline. The range is quite asymmetrical, it has a gentle western slope, and a steep eastern slope towards the Orontes river valley. At the south and north ends the mountains gradually become lower. The highest elevation (1563 m) north of Slenfeh, is in the northern part at Jebel Matta.

The summit zone is 2-3 km wide in the north, it broadens to 4-6 km in the central part, and narrows again to 1-3 km in the south. The elevation of ridges in the summit zone varies from 1000 to 1400 m. The western spurs drop abruptly from 800 to 200 or 100 m and rim the coastal plain that extends from Lattakia to Banias.

The Bassit-Bayer hills in the north are a series of short ridges, the southern and south-eastern ends of the Akra range in Turkey. The Lattakia mountains (1200-1400 m) are the highest in Syrian territory, their spurs lowering and merging into a coastal plateau towards the south west, but dropping sharply in the south and southeast towards the North Kabir river valley.

The coastal plain (a broad inclined surface) stretches to the west of the Jebel as Sahel foothills, and is divided by rocky spurs of the mountain massif into several sections: Lattakia, Jableh, Banias, Tartous-Hamidiyeh and Akkar.

To the north of Lattakia Cape the raised plain merges with a coastal plateau, and it ends next to the steep high Bassit Cape. Towards the southwest the coastal plain is first a narrow strip, then south of the Banias hills it gradually broadens, and joins up with the Akkar inter-mountain plain, which is crossed by the South Kabir river. In places the plain is elevated by steps and sometimes it rises gradually from the seashore to the foothills.

Plateaux are peculiar orographic elements of the coastal region: the north coastal plateau, tied to the Bassit-Bayer Hills, the Al Markab-Banias, and the Tell-Kalakh, which rises in the centre of the Akkar inter-mountain plain. The first of these is clearly inclined towards the sea and is dissected by small valleys and gullies. The highest elevation of the plateau is 300-400 m above sea level. Its western ledge merges into the coastal plain. The Markab-Banias plateau is 200 to 600-650 m high, its steep ledge falling abruptly to the sea, at the Banias peninsular.

The Tell Kalakh plateau forms a sloping surface, its summit lies beyond the coastal area (Ahin plateau). To the southwest, it drops by rather steep steps or ledges to the Akkar plain. Elevations vary from 450 to 100 m above sea level.

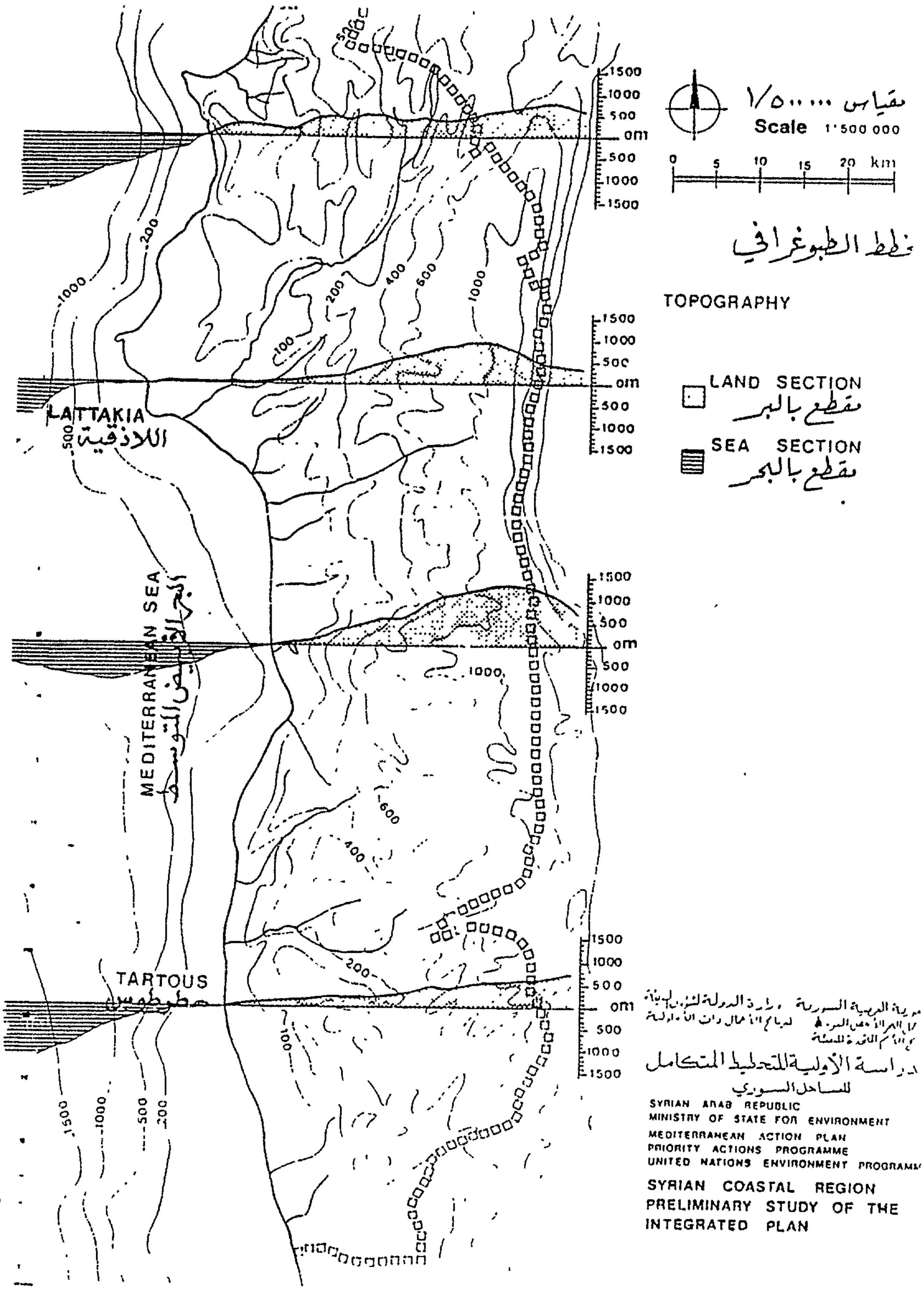

Figure 27 - Topography and relief of the Syrian coastal zone

2.2.2. Geology

The Syrian coastal region lies at the extreme northwest of the Arabian-African plate as a very small marginal zone that has been disturbed by many tectonic movements, as it is located close to the meeting point with the Turkish-Aegean plate. The Jebel as Sahel ridge is a large arched structure, a complex anticline associated with the northern extension of the great Arabian-African faults (the Aqaba, Dead Sea, Jordan valley system). The limits here run along the Nahr Al Kabir As-Shamali (North Kabir River) valley through the so-called Lattakia-Killis Neogene - Quaternary depression, which separates the Jebel as Sahel from the Amanaus and Al-Bassit highs. To the east of the region another major tectonic margin is the graben of the Shab plain.

As a consequence of this tectonic situation the Syrian coastal region is unstable and earthquakes have been a distinctive consequence of crustal movements. Earthquakes have been felt many times from antiquity until the last century, with devastating results in the years 348, 529, 859, 1105, 1113, 1170, 1178, 1202, 1747, 1822 and 1872. The region lies in a 7th degree earthquake zone, on the Mercalli scale (which has a maximum degree of 12).

The Jebel as Sahel mountains are constructed mainly of Jurassic and Cretaceous limestones and dolomites, overlapped in the western slope and valleys by Paleogene and Neogene marls and limestones, and by volcanic rocks (Figure 28). The limestones and dolomites are fractured and often karstified. In the Bassit mountains there are rocks of magmatic origin like diabase, syenites and the so-called "greenstones" or ophiolites.

The Cretaceous limestones are widespread throughout the middle elevations and lower parts of the mountains, and outcrop as far as the coast at Tartous. Late Cretaceous (Maastrichtian age) clayey limestone and marls cover the foothills of the Jableh coastal plain, and several separated patches towards the north. They are white, chalk-like, soft rocks, of low resistance to erosion. These formations are often deeply incised and barren, having a characteristic landform which affects the rural environment, especially agriculture and communications.

The Al-Haffeh foothills in the north, as well as small areas in the south, contain rocks of Tertiary age, mostly marine clays, marls, sandstones, clayey limestones and conglomerates. The coastal hills of the middle section between Banias and Tartous, and in the Safita-Driekeesh areas, are made of Tertiary volcanic (eruptive) rocks with tuff-breccias and basalt layers 50 to 150 m thick. The lowest areas of the region; the coastal plains and the river valley beds, are made of quaternary, unconsolidated loams, sandy loams, sands, clays, conglomerates, sandstones and limestones of marine and alluvial origin.

A complex of terraces of Quaternary marine sediments can be seen in the coastal lowlands and foothills, up to 215 m above sea level. The sediments of these terraces are more consolidated than the other Quaternary sediments of the region.

2.2.3. Landforms

The Syrian coastal region comprises six geomorphological zones: shoreline, coastal plain, hilly country, river valleys, foothills, and mountains (Figure 29), the characteristic features of which are described below.

2.2.3.1 The coastal zone

Several types of shoreline are present as summarized in Table 10.

In terms of area, the coastal flatlands and hilly country are the most extensive in the 10 km wide coastal zone. About 60% of the total area belongs to the category of "coastal plain", a further 30% is hilly country, and the remainder (<10%) forms the shoreline (beaches, dunes, cliffs) and river valleys.

There are two major alluvial plains, the Jableh-Lattakia plain in the north which is approximately 50 x 10 km; and, the Akkar plain in the south which is very narrow just south of Tartous, broadening to more than 10 km wide near the border with Lebanon. Both plains gently slope towards the sea.

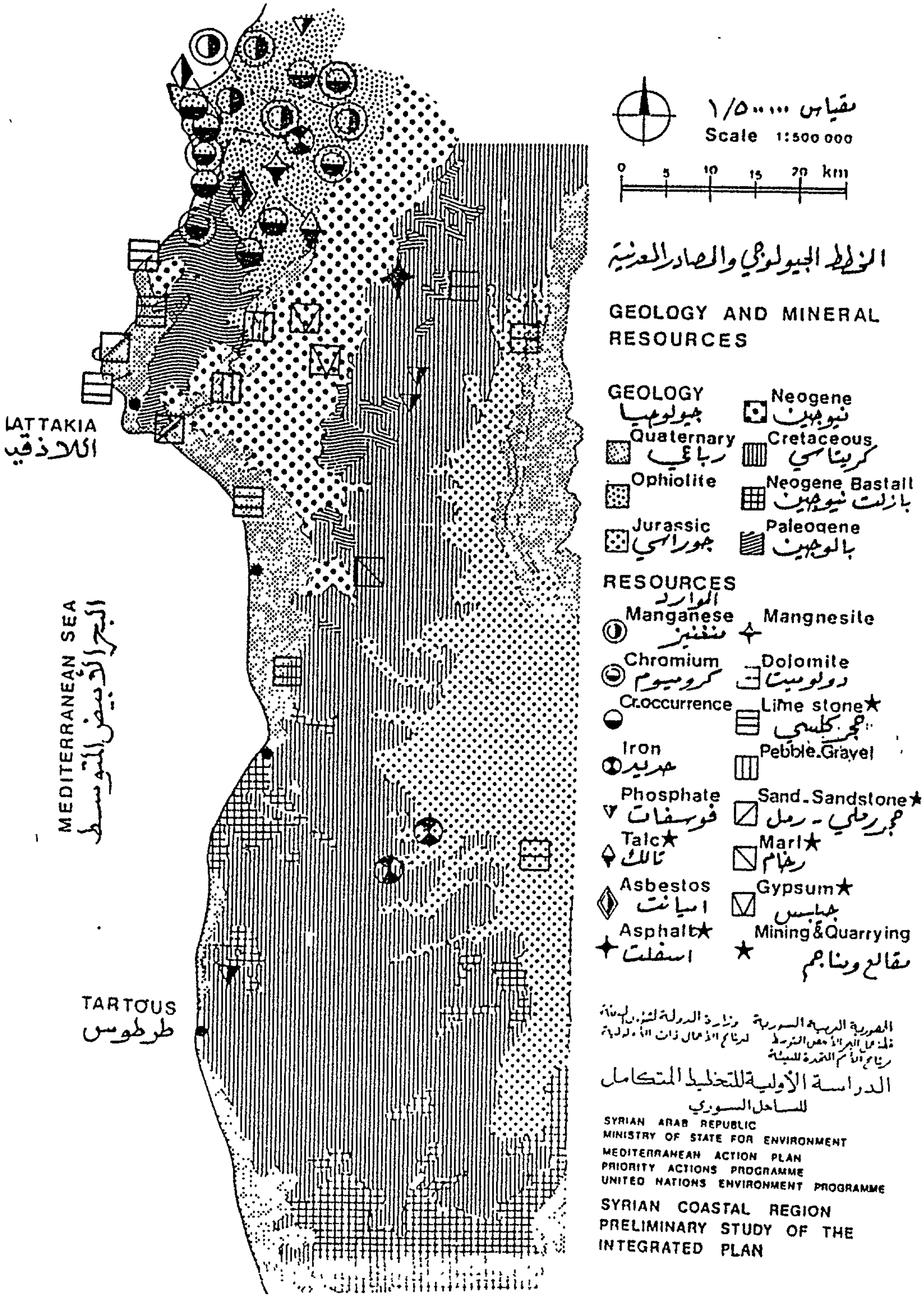

Figure 28 - Geology and mineral resources of the Syrian coastal zone

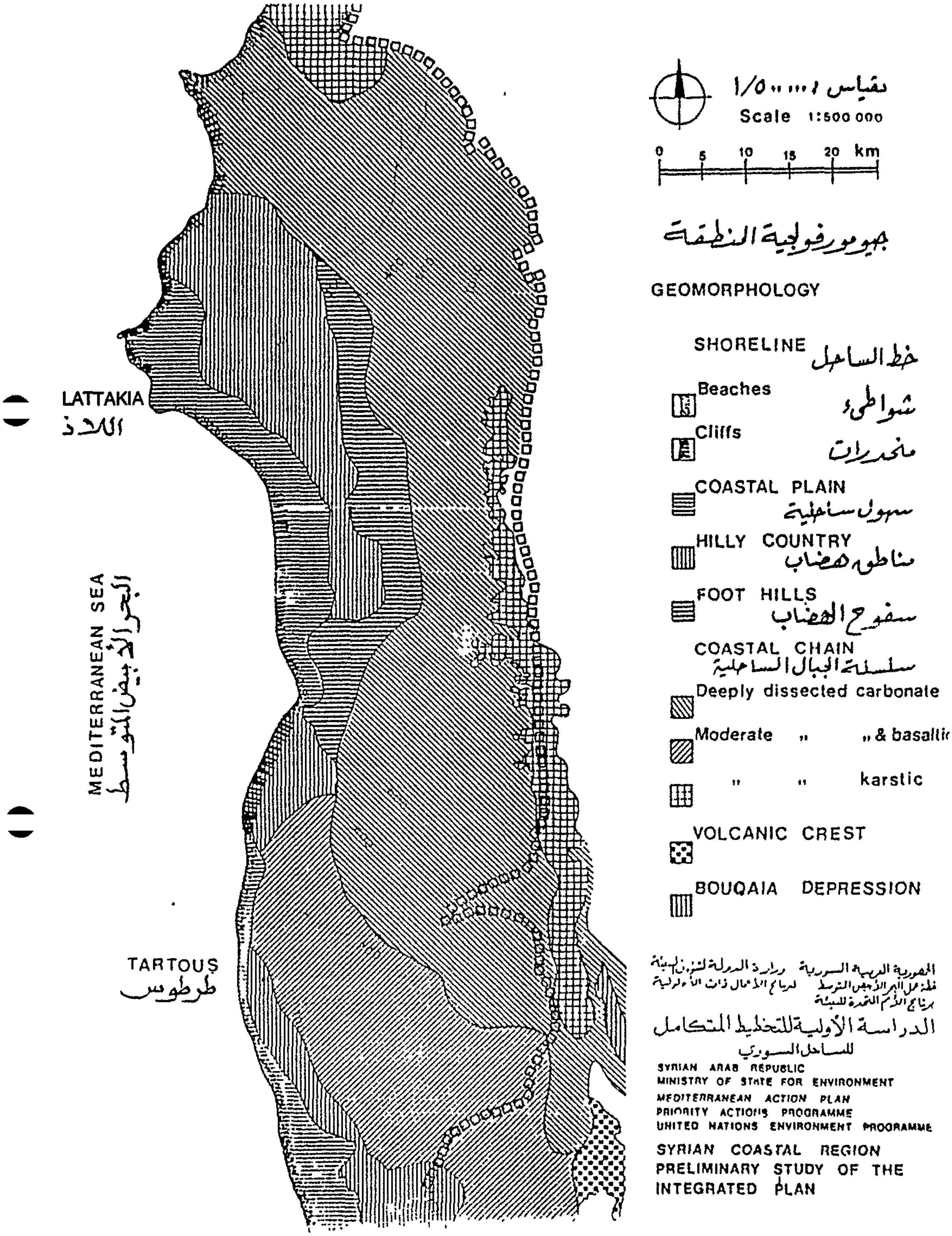

Figure 29 - Geomorphology of the Syrian coastal zone

TABLE 10

Schematic classification of Syrian shoreline types

SHORELINE TYPE	NATURAL	BEACHES	SAND	WITHOUT DUNES
				WITH DUNES
			GRAVEL	
		ROCKY SHORES	ROCKS	FLAT
				STEEP
			CLIFFS	LOW
				HIGH
	ARTIFICIAL	URBAN WATERFRONTS		
		PORT AND TERMINAL FACILITIES		

Beaches extend all the way from Lattakia to the Lebanese border and are relatively evenly distributed along the entire coast with relatively short breaks south of Jableh and south of Banias. The most important beaches are: the 25 km long, 1 km wide, straight sandy beach between Tartous and the border with Lebanon, which lies at the edge of the Akkar plain and is backed by dunes; the 13 km long, 1 km wide, sandy beach with large sand dunes, southeast of Lattakia which is supplied with sand from the North Kabir River; and, the 10 km long, sand and gravel beach in the far north, between Badrussiyah and Ras el-Bassit.

Other important beaches are those at Om At-Touyour, Wadi Qandeel, Ras Ibn Hani, north of Banias, north of Ras el-Hussain, and north of Tartous. In addition, there are several groups of small "pocket" beaches, developed within rocky shores and in between cliffs. Very scenic sections of this type of coast are to be found between Ras el-Bassit and Om at-Touyour, and to the north and south of Jableh.

The sand dunes of the coast are old (Quaternary) fixed dunes composed of slightly consolidated, light coloured, calcareous sandstones. The younger dunes are formed of loose brown sand. The beaches are made of biogenic and terrigenous sand. Overall they are retreating because stream supply of sediment is small. Beach slopes are low, but in many parts the upper beach is bordered by a 1-2 m cliff cut in late Quaternary sandstones.

Coastal sections with high cliffs occur north of Badrussiyah (Jebel al Akra); the "white cliffs" between Ras el-Fassouri and wadi Qandeel; and, the rocky coast south of Jableh. In front of this coast there are five small islands of which Arwad island is the largest and the only inhabited one. It is about 200 hectares and is located only 2.3 km from the coast, and 3.8 km from the port of Tartous (where there is a special small harbour for communication with the island). The island is made up of a Quaternary calcarenite which was much used as building stone in antiquity.

Generally, the low and high cliffs are fronted by an irregular, almost flat shore erosional platform, a little below high tide.

2.2.3.2 The mountains

The upper mountains have a rugged, rough and wild terrain characterized by outcrops of usually hard rocks, but liable to solution processes and therefore with a well developed karstic topography. This includes large and small dolines, sinkholes, rugged and grooved terrain and barren rocky ground without surface streams. Smaller shallow dolines, funnel shaped depressions and other karstic features formed by solution in limestone, are distributed throughout the mid-altitude zone of the mountains.

The deep valleys and gorges are formed mainly by running surface water, also with the help of solution processes. West of the upper karstic zone, the higher parts of the dry valleys begin to acquire open V-shaped cross sections, but they change, very soon, into deep ravines and gorges through which the streams flow, particularly after heavy rains. There are more than 15 main stream gorges or box-shaped valleys.

Erosion resistant calcareous rocks extend across the middle montane area between the margins of the uplands and the foot hills, i.e. between 750-800 m and 150-200 m above sea level. The valleys are more open and bear deposits of materials eroded from the higher slopes. The geomorphology of the soft clay limestones and marls of the lower parts of the mountains and foot hills has other fluvial landforms: a dense network of short gullies, with a dendritic form of drainage system ("badland"). The western slopes of the mountains of Jebel as Sahel are the zone of highest erosion activity, not only in the coastal region, but also in the whole of Syria.

2.2.4. Soils

The soils of the coastal region are genetically related to the lithology of the components. Overall, the red and red-brown soils of Mediterranean type are predominant. A thin layer of coarse-skeletal, fine earth is observed only in the slopes of the mountains on rocky outcrops of limestones. The foothills are mainly covered by shallow detritus of red-brown or grey-brown colour. Poor calcareous clay reddish-brown soils are developed on loams, conglomerates and basalts. Meadow-boggy soils, rich in humus, overlie Pliocene and Quaternary clays in the depressions. The average thickness of soil cover on the slopes is 0.10-0.25 m, in the river valleys up to 1.0 m or more.

In spite of the limited extent of the coastal region, there are several distinctive soil types with different degrees of fertility and productivity covering the plains and small areas in the mountains. The most predominant and fertile soil type, especially in the plains, is the *"terra rossa"*. In the mountains, the *terra rossa* forest soils are of exceptional value. However, in general this soil is discontinuous, thin and liable to erosion. A detailed soil map of the uplands shows a vast "Jurd" (bare) surface with scattered small islands or very narrow strips of *terra rossa* brown forest soil cover. This is generally very thin (20-30 cm) on the flat and gentle sloping surfaces, and over 1 m in the bottoms of dolines and low hollows.

The middle zone of Jebel as Sahel between the karstic upland and coastal plains contains other parent materials besides limestone and dolomite. They produce various soil types as a product of the close interaction between rocks, climatic conditions and other natural environmental elements.

The most common soil types in this zone are brown forest soils on the relatively steep mountain slopes, *terra rossa*, rendzinas and *terra rossa*-rendzina complexes, on the less steep surfaces. Rendzina soils are found on soft limestones and marls, usually in association with other types, especially *terra rossa*. As a general rule these soil types are enriched with colluvial materials including fine sand, coarse and medium material. The soils of the marly and clayey limestone hills east of the Jableh plain are white, thin and highly calcareous.

Throughout the coastal plains the predominant soils are also of *terra rossa* type, but derived from undifferentiated and unconsolidated materials. They are formed on sands and conglomerates, are non-calcareous and brown. The highest quality agricultural soils occur in the western parts of the Jableh and Akkar plains.

The fertile red soil contains clay and loam and it varies in depth from a couple of centimetres to more than one meter. Its pH is 7-8. The comparatively small amounts of crumsol give a clay dark brown colour to the soil. In valleys, soils are of alluvial origin and occur in depths of more than 100 cm. In the southeast part of the region the soils derived from volcanic rocks are dark in colour.

2.2.5. Slope and soil erosion

Rainfall erosion modifies drastically the capabilities and distribution of soils. It is in fact, a major limiting factor to soil formation and retention. Under natural conditions the vegetation cover plays a positive role in reducing soil erosion, but unfortunately it has been extensively degraded, under human impact over several thousand years.

Generally soil erosion is a problem in the Coastal Region of Syria due to a combination of torrential rainfall, deforestation, forest fires, and inadequate reforestation.

In terms of vulnerability to erosion, there are four zones:

1. the first is an area of low susceptibility, which covers the large plain south of Lattakia to 100 m altitude with slopes of less than 3 per cent (total area approximately 90,000 ha);

2. the second zone of slight susceptibility, covers most of the areas north of Lattakia up to 50 m altitude (about 50,000 ha). Like the first zone, the slopes are gentle, not more than 3 per cent. Sediment yield in zones 1 and 2 is generally under 30 t ha^{-1} yr^{-1};

3. areas of high susceptibility to erosion cover as much as 330,000 ha, that is more than 65 per cent of the coastal region. They include the northwest corner of the country and the slopes of Jebel as Sahel, from 100-1,500 m altitude and having gradients of 45 per cent or more. Sediment yield varies from 30 to 60 t ha^{-1} yr^{-1}; and

4. finally, there are areas that are strongly susceptible to erosion, covering approximately 32,000 ha. They can found mostly in the hilly part of the coastal plain, northeast of Lattakia, and between Banias and Tartous where the altitude ranges from 100 to 600 m and the slopes vary from 15 to 35 per cent. Soil losses can amount to 50-100 t ha^{-1} yr^{-1}.

In conclusion, approximately 75 per cent of the region is likely to be affected by high or severe rainfall erosion and Figure 30 illustrates the areas exposed to soil loss, expressed in tons per hectare, per year.

2.2.6. Consequences of climate changes and of sea level rise

2.2.6.1 Introduction

Independent of future climatic changes, the soils, slopes and beaches of the Syrian coastal region are presently and for the immediate future, threatened by factors of human origin. The recent construction of dams on several rivers, which normally transport considerable quantities of sediment to the coast, will slow down or stop entirely the supply of materials (sand, silt, pebbles) for beach formation. The result will be, thinning of the beach strip and the erosion and recession of the coastline. To this depletion must be added losses resulting from the excavation of sand for building purposes. This is carried out almost everywhere, but is particularly common in the area of the sand-dunes behind the beach southeast of Lattakia and, on the beach from Tartous to the Lebanese border.

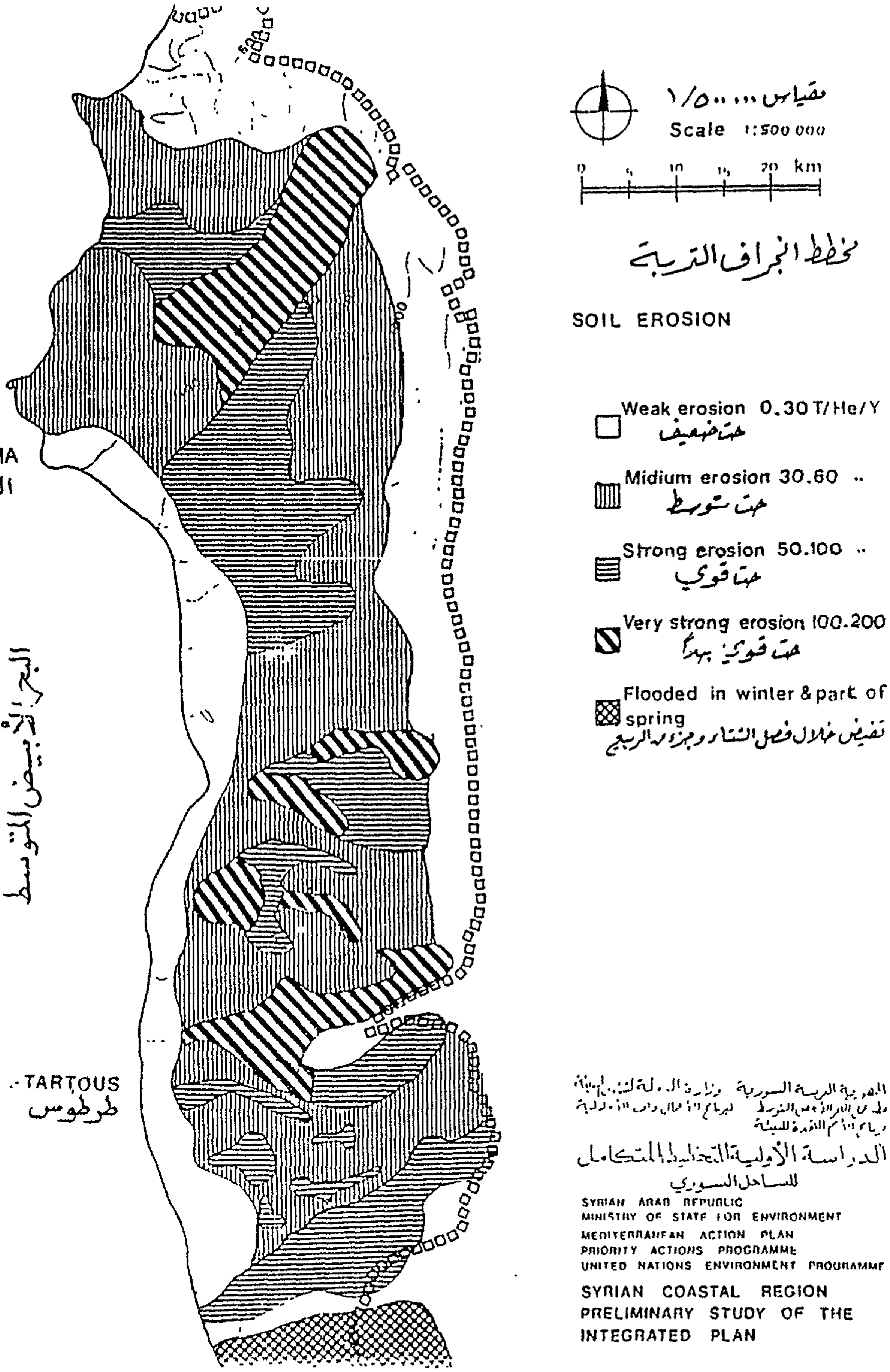

Figure 30 - Soil erosion map of the coastal region of Syria

2.2.6.2 Impacts on coastal stability

There is no information on recent or current land movements at the coast, but it is likely that subsidence is not occurring, given that the Hatay (Turkey)-Syria-Lebanon coasts have been rising in the recent geological past (Sanlaville, 1981, 1985; Pirazzoli *et al*, 1991). Thus in relation to sea level rise during the next 100 years the land will probably remain stable under sea level change scenarios of +12.5 cm by 2030; +22 cm by 2050; and +28 to +60 cm by 2100.

Sediment supply is generally low, except near the main rivers, and the beaches have a low gradient; many are narrow. However, because of widespread low cliffs at the top of the beaches, a sea level rise of ± 25 cm would have only minor impacts except in cases where buildings are too close to the shore or, if the frequency of storm surges were to increase. Even if this is not the case, damage to buildings would become more frequent than today, because the present, relatively low winter waves and the small tidal range, have encouraged the construction of private houses and tourist hotels too close to the present shoreline.

Sea levels higher than 40-50 cm above present would cause local flooding, thus it will become necessary to move buildings and to elevate infrastructure such as port defense walls.

2.2.6.3 Impacts on soils and slope stability

At present soils in the coastal region are in general rich in organic matter, and chemically influenced by parent materials, especially calcareous rocks. Due to relatively low rates of rainfall, agricultural soils are kept moist during the dry season by irrigation.

Even if precipitation remains of the same order of magnitude as today, the temperature increase will raise potential evapotranspiration, over the year and especially during the longer summer. Therefore, soils will generally contain less moisture, less organic material, and their aggregate stability will decrease.

At present, quantification of the impacts under the scenarios of future climate changes, is impossible, due to a lack of quantitative data and knowledge concerning the interrelated responses of soil parameters and erosion under changed climatic parameters (Imeson and Emmer, 1992).

In general, it can be predicted that:

- soil will be more erodible, especially on slopes;

- there will be greater concentrations of sediment in slope runoff, and more overland flow during extreme rainfall events;

- more sediment will be delivered to the main streams, more substances will be taken into solution from marly badlands and from calcareous rocks;

- stream channels could change shape, and flooding could be more frequent; and

- there would be higher susceptibility to forest fires.

2.3. Hydrosphere

2.3.1. Terrestrial Hydrology

2.3.1.1 Introduction

The hydrological conditions of the coastal region are determined by its climate, geography and geology. The coastal region belongs to the Mediterranean humid or subtropical type of climate, with the rainfall and temperature gradually increasing from the west to the east and the amount of rainfall gradually increasing from the lower to the higher slopes. Frost is rare but snow is quite frequent in the areas around Slenfeh which are higher than 1,200 m above sea level.

The distribution of rainfall over different areas in the coastal region is shown in Tables 2 and 3 and in Figures 7 and 8. It can be seen that most of the coastal area receives less than 1,000 mm of precipitation yearly; the area above 1,500 m such as the upper slopes and ridges in the east, receive the largest amount of rainfall, up to 2000 mm yr^{-1}. Most precipitation is concentrated in winter (November to March). The average evaporation values are given in Figure 15. Table 11 shows the capacity of freshwater sources by mantika.

TABLE 11

Freshwater resources of the Syrian Coastal Region

Mantika	Spring $L\ sec^{-1}$	Wells $m^3\ hr^{-1}$	Dams $m^3\ day^{-1}$	Name of dams
Lattakia	133.0	1420.0	5654.0	Baloran
Ali Haffeh	706.0	125.0	2664.0	Al Haffeh
Al Qardaha	190.0	353.0	1200.0	Nina el Baida
Jableh	296.0	53.0		
Tartous	275.9	1919.7		
Banias	838.8	102.0		

(Source: statistical abstract for Lattakia and Tartous,1981)

There are 17 rivers and streams in the coastal region (Figure 31) which vary in length from 6 to 96 km (the North Kabir river is 96 km; the South Kabir river 50 km). Water discharge varies from a minimum of between zero and 5.6 $m^3\ sec^{-1}$ in the Kabir ash Shemali in summer, to a maximum of between 2 and 55 $m^3\ sec^{-1}$ in winter.

2.3.1.2 The water cycle

The water balance of the coastal region has been estimated by assuming a 60% loss from evapotranspiration; a 30% runoff factor; and a 70% recharge to groundwater from the remaining net rainfall. The average annual rainfall is 1068 mm, the net annual rainfall after evaporation is 427 mm. The estimated surface runoff is 300 mm.

These assumptions result in estimates of 6 million cubic metres of surface runoff and 625 million cubic metres of groundwater recharge annually. Of these quantities only a portion, probably not exceeding 50%, is readily available due to losses to the sea, surface runoff and losses to deep penetration.

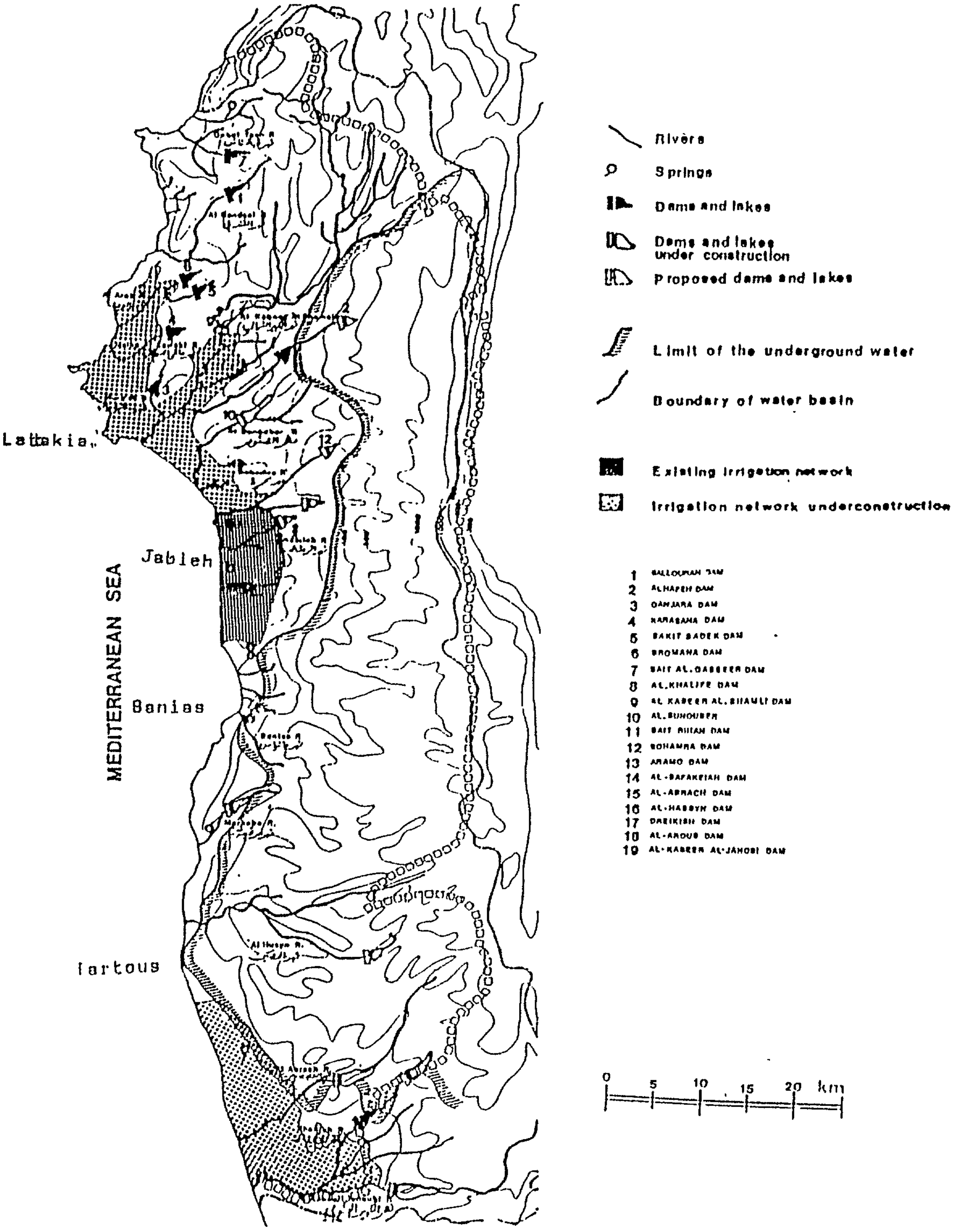

Figure 31 - Water resources of the Syrian coastal region

Runoff data for various springs and streams at selected localities for 1990 are given in Table 11. The figures refer to instantaneous flows, and estimates of the total flow from each source for the larger part of 1990 can be derived from these and similar data.

The extensive groundwater table is relatively shallow, so there are many springs, other water sources and wells. The major spring is that of the Al Seen river, which breaks out of a limestone cliff below the mountains, 6 km from the coast. At present the Al Seen spring yields 7 to 25 m^3 sec^{-1}. A small lake has been created by the construction of a dam across the outlet.

The second important source is the Goreen spring (290 l sec^{-1}) located in the Hamma Mohafaza (Hamma Province). In addition there are some 80 or so small springs with a total capacity of 3.60 m^3 sec^{-1} and some 160 wells with a total capacity of 3.70 m^3 sec^{-1}.

2.3.1.3 Water resource management

The hydrological situation of the coastal region is satisfactory. Due to the rainfall and the abundance of limestones there is a well developed network of underground as well as surface water courses. The major sources of fresh water supply in the region are springs, wells and artificial lakes (Iacovides, 1991).

Al-Seen is the most important source. The existing and planned network fanning out from it covers a large portion of the coastal part of the region where the largest towns and the main agricultural areas are located.

Most of the water is used for irrigation, whilst a sizeable amount is pumped, treated and used for the domestic supply of Lattakia, Tartous and for industries. The relative volumes consumed are: 5.0 m^3 sec^{-1} for irrigation; 1.1 m^3 sec^{-1} for the city of Lattakia; 1.05 for the network feeding the Tartous coastal strip and Arwad Island; 0.27 m^3 sec^{-1} for cooling at the Banias oil refinery; and, 0.45 m^3 sec^{-1} for the settlements in the coastal strip south of Lattakia.

The remainder of the region, with the exception of a small area in the northeast section of Tartous Mohafaza, is supplied from small springs and wells connected to individual supply networks.

Currently, a number of fresh water supply projects are under construction or in a planning phase. They are:

- the extension of the Al-Seen project to the city areas of Tartous, Hamidiyeh and Arwad;
- the Kassab and Ras-El-Bassit project;
- the extension of the Hamma water supply network to the area of Slenfeh;
- additional water supply for Lattakia from the Kabir reservoir (600 l sec^{-1}); and
- a water supply network for the northeastern area of Tartous Mohafaza which has no supply at present.

Once these projects are completed, the entire region will be covered by the water supply network, and the existing high coverage of the fresh water supply to households (100 % in urban and 70 % in rural areas) will be further increased.

2.3.1.4 Water quality

The supply of adequate and safe drinking water to the communities of the coastal region is one of the authorities' top priorities. Unfortunately, there are both water supply and water quality problems. The low pricing of water, which is free to industry has led to irrational use; there is a 40% loss from poorly constructed and maintained mains and illegal tapping; the quality is low, since chlorination plants are not properly maintained; and, pollution is widespread.

Fresh water pollution affects both the ground water and river sources of supply. There are three major sources of pollution: domestic wastes from farms and villages; agriculture run-off; and, industrial effluent discharge.

The chief cause of contamination of water supplies results from the practice in a number of villages, that have partial or no sewer system, of discharging the untreated sewage into the nearest stream. This sewage is normally absorbed into the stream beds within a short distance but may end up in lakes, springs and wells. The sewage which contains human and/or animal excrement pollutes downstream water supplies with pathogenic micro-organisms.

Chemical contamination, which may also be a source of pollution affecting drinking water supplies, results from the chemical waste products of industry and chemicals used for agriculture, particularly fertilizers and pesticides. Excessive levels in drinking water have been claimed to be responsible for the high levels of methaemoglobin in children. Inland waters, however, are not affected by industrial pollution since most of the major industries are near the coast.

Unregulated pumping of ground water for irrigation in the coastal region, has led to salinization of the soil, resulting from sea water infiltration into the groundwater.

A survey of domestic water supplies was undertaken in 1989 and of the 50 individual samples examined, 40% had zero faecal and total coliforms and 40% had indications of 4 or fewer faecal coliforms per 100 ml. The remaining 20% of samples had more than 10 faecal coliforms per 100 ml, with at least 7 instances where the count exceeded 1,000.

Samples of water analyzed in 1989 from 20 individual springs indicated the presence of faecal coliforms in almost all; counts of more than 100 per 100 ml were common. Where analyses were made, Biological Oxygen Demand (B.O.D.) values were within acceptable limits, although B.O.D. for springs indicated the short travel time of groundwater which is probably due to its karstic nature. In the case of Al Saffrakieh, the B.O.D count was around 8, indicating a rather high degree of pollution. The dissolved oxygen values indicate well oxygenated water. It is obvious that a large number of springs are also polluted from sewage disposal.

Eight reservoirs were sampled in 1990. Faecal coliforms were found in most samples although the B.O.D. levels indicate that they are well within the acceptable limits whilst the water appears to be well oxygenated. In the Al Seen lake analytical results indicate that the faecal coliform count is generally low. There is an indication of pollution, and although the B.O.D. level is within acceptable limits, the excessive growth of algae is a serious problem in the lake.

All of the analytical results of river water indicated a high degree of faecal coliform contamination suggesting pollution from sewage and farm animals.

2.3.2. Marine hydrology

Information about the physical characteristics of the Mediterranean sea water off Syria is still limited, but data should become available as the results of recent Russian investigations carried out in co-operation with the Scientific Research Centre, and the Navy Research Centre become available.

The patterns of horizontal and vertical circulation of water masses in the eastern part of the Levant Basin were studied under the POEM project in 1985-1988 (Oszoy *et al*, 1991) The area between Syria and Cyprus was partially covered, beyond the continental shelf (0 -200 m). The bathymetric contours of hydrographic charts indicate that the continental shelf is very narrow; the isobath of 500 m depth runs at an average distance of 10 km off the coast.

Preliminary oceanographic data, provided by the Marine Research Institute in Lattakia, indicate that wave directions are generally from W and SW, with average storm wave heights of 1 to 2 m (maxima of 5 m and, 10 second periodicity). Exceptional storm surge events had 7.8 m waves. The tidal range is low, with maximum spring tides not over 40 cm.

Longshore drift is generally to the north and steady offshore currents have a mean velocity of 30 cm sec^{-1}. Salinity is high (39 $^{\circ}/_{oo}$); average water temperature is around 17 °C in March, 28 °C in August.

In regard to water pollution, there is a programme to monitor the quality of sea water, being undertaken in co-operation with UNEP/MAP encompassing chemical and microbial analyses at more than 30 sampling points along the Syrian coast. Preliminary results indicate that some areas such as those to the south of Lattakia and to the north of Banias are polluted with faecal coliforms.

Table 12 provides a relative measure of the cleanliness of Syrian coastal sea water based on data for heavy metal and nutrient concentrations in sea water and biota, in samples collected in 1990.

TABLE 12

The level of clean sea water according to Geneva document, 1985

Location	Level of clean sea water
Ras Al Bassit	87 %
Om Al Touyour and Wadi Kandil	98 %
The north of Lattakia	89 %
The south of Lattakia	29 %
The north of Jableh	68 %
The south of Jableh	86 %
The north of Banias	20 %
The south of Banias	77 %
The north of Tartous	45 %
The south of Tartous	84 %

2.3.3. Likely consequences of climate changes

Water supply and use in semi-arid lands are very sensitive to small changes in precipitation and evapotranspiration because the proportion of precipitation that runs off or percolates underground is small.

Increase in atmospheric temperature would undoubtedly lead to greater evaporation and to changes in soil moisture and water content. The most important climate variable that may change is regional precipitation. The operative scenarios suggest the possibility of higher winter and spring precipitation, but the amount is uncertain (Figure 19). This greater precipitation could offset the greater evaporation. However, as noted by the Climatic Research Unit (1992) confidence in these scenarios is low at the moment (section 2.1).

One of the most important outcomes from the IPCC review has been to make clear that physical and social scientific understanding is not yet at a level where water resource impact assessments are practical, as the regional details of greenhouse-gas induced hydro-meteorological changes are virtually unknown (Lins *et al*, 1990).

This is especially critical for evaluating the potential impacts on agriculture; for the design of water management systems; and, for producing reasonably accurate water supply estimates. One may perhaps estimate impacts in Syria on the basis of three scenarios: a) possible total rainfall increase; b) drier and hotter summers; c) precipitation same as at present. It is certain however that changes in hydrological extremes in response to global warming will be more significant than changes in mean hydrological conditions.

Increase in atmospheric temperature would result directly in increased water demand for domestic, industrial and agricultural purposes and at the same time would result in water losses through evapotranspiration and wastage. However transpiration losses may be partially offset by reduced plant water use in a CO_2 richer atmosphere.

Higher temperatures would also have an impact on the winter snow cover with more winter precipitation being in the form of rain resulting in greater winter run-off and decreased spring snow melt flows. If this additional winter run-off cannot be stored in view of flood control considerations or a lack of adequate storage then the end result would be a loss in usable water supply.

Atmospheric warming would lead to changes in the components of the lake and reservoir water balance (precipitation, inflow and outflow, evaporation); the water levels and the heat budget. These changes would be different in the case of unmodified drainage basins and dammed systems. Sedimentation in reservoirs could increase due to more loosely textured soil.

Temperature increase would result in small rivers and shallow reservoirs being dry more frequently; water quality in many bodies could deteriorate.

Other consequences of global warming include changes in total water amount and levels, erosion of riverbeds, and modification of turbidity and sediment load. Overall decreasing river run-off and lake levels could decrease the possibility of dissolving pollutants and flushing.

The climatic conditions generated by global warming would probably also affect marine circulation (Gacic *et al*, 1992) as Mediterranean hydrology is closely related to climate and its highly variable atmospheric forcing. Warming may alter: the distinctive eastern Mediterranean stratification of water masses and their seasonal vertical movements. The complex water circulation (gyres, jets, eddies, meandering currents) features an irregular distribution of density, with entrapment by eddies of both Atlantic (surface) and (intermediate) Levantine water, and the re-distribution of surface heat by currents (Oszoy *et al*, 1989). Higher surface water temperatures are expected to occur eventually, with some changes in winter versus summer thermohaline stratification.

The impacts of future wave regimes will depend upon changes in storm direction, hence on the number and direction of cyclones passing through the eastern Mediterranean. The relative future importance of winds blowing from SW, SSW (see 2.1.7) and the importance of exceptional events is shown by the storm surge in early January 1968, when waves over 8 m high and wind speeds of 140 km hr^{-1} caused flooding of parts of the city of Tartous.

2.4. Atmosphere

2.4.1. Atmospheric pollution

As the Syrian coastal zone is a part of the eastern Mediterranean shores, it is exposed to pollutants in the atmosphere from different sources. When the winds are from the west, pollutants come from neighbouring countries and from factories in the coastal region itself. When the wind is from the north, south, or east airborne pollution comes from the inland areas. The central area of the coast is the most polluted. Although there are no measurements of air pollutants in the coastal region as a whole, there are some data for the two cities of Tartous and Banias.

In Tartous, the existence of nitrogen oxides, carbon monoxide and sulphur dioxide in the air has been noted; however, not above the allowed limits. The pollutants derive from urban activities, mainly from car exhausts and from the Tartous cement factory. Ozone gas ratio is inversely related to nitrogen oxides.

It should be noted that dust concentrations are higher than the allowable levels, especially in the Free Area as a result of phosphate loading from the harbour and from the cement factory. The high concentration of suspended dust in Tartous reflects the polluted situation of the city.

In Banias, measurements of air pollution in four different areas, indicate that the source is mainly emissions from the oil refinery and from the thermal plant. The existence of nitrogen dioxide was noted, sometimes with a concentration higher than the permitted levels. The concentration of dust in suspension is higher than allowed.

2.4.2. The consequences of climatic changes

It is expected that pollution due to human activities will increase over the next few decades, especially due to the rising need for energy with increasing population. There will be more energy generating plants, as well as factories and private cars. Pollutant emissions will increase, unless restriction on emissions both private and industrial are enforced and cleaner energy sources used.

Future air quality and pollution levels will depend on the impact of global warming on atmospheric processes in urban areas including cloudiness, precipitation, solar radiation, visibility and winds. If the level of air pollution is not brought under control and maintained at acceptable levels and the present situation persists under significantly warmer climate conditions, the situation near industrial centres and cities will worsen considerably.

2.5. Natural ecosystems

2.5.1. Terrestrial ecosystems

There are six distinctive ecosystems in the Syrian coastal region: dunes/beaches, sea cliffs, wetlands, riverine woods, forests, bushland and thickets. Detailed information on the biocenoses, species composition and dynamics is mostly lacking.

Wetlands. Due to the calcareous geology and the high permeability of the coastal region, wetlands are scarce and of limited extent, being found only near river mouths. The largest of the remaining wetlands is Buhairat Al-Laha (5 ha), which contains a variety of aquatic species, birds and halophilous plants. It is threatened by the expansion of cropland and by chemical pollution. Another smaller wetland is Buhairat Laraba (2 ha).

Riverine woods. Most of the rivers in the coastal area have short courses, but approaching the coastal zone and the sea they become wider and slower and both banks are, in many places, covered by luxuriant woods, with distinctive plant species, small mammals, birds and invertebrates.

Forests. Although natural forests have been drastically reduced in the coastal region, there are still two large parts of the coastal region where original species are preserved and prevail over other forest species. They are the Bassit upland (various species of oak and *Pinus brutia*), and the middle and high parts of Jebel Saheiligheh (*Cedretum libani* and *Quercus pseudocerris*). As cedars have become so scarce in Syria, they should be considered as the most precious botanic heritage, that must be preserved with careful protection. The oak forest north of Slenfeh has deteriorated due to cutting and to acid rain.

Woods and Bushland. Undergrowth (coppice woodland) is as important as the tall woods since bush will develop after some years into a climax forest. Bushland and thickets constitute a possibility for recovery of natural forest and are as efficient as the taller species in counteracting and stopping soil erosion processes. There are three large areas of bushland: the coastal strip (*Pistacia* and *Quercus* species); the hilly zone (oak species in valleys and canyons); and, the mountain zone where taller trees cannot develop, as in the case of the Bassit area at an altitude of 800 m and above, and Jebel Saheiligheh at altitudes above 1,200 m.

In terms of vegetation, the region can be divided into four main areas:

1. the Lower Mediterranean zone (to 400 m elevation) extends from north to south and includes the coastal strip and plains. This is the centre of distribution of *Quercus lentiscetum*, with some *Quercus calliprinos* (the evergreen oak) and *Quercus infectoria*;

2. the Middle Mediterranean zone (400 to 1000 m altitude) includes the highest parts of Jebel Saheiligheh and the Bassit upland, where, *Quercus infectoria* dominates over *Quercus calliprinos*. There is also *Pinus brutia*, mainly in the northern parts of the Bassit area;

3. the upper Mediterranean zone (above 1,000 m altitude) includes the high levels of Jebel Saheiligheh predominantly covered by *Quercus pseudocerris* accompanied by *Pinus brutia;* juniper, *Juniperus*; the ash tree, *Fraxinus*; and occasionally by fir, *Abies cilicica*; and

4. in the Cedar zone (above 1,400 m altitude) the cedar of Lebanon is the dominant species, with some species of oak and fir. Cedars mostly grow on the eastern slopes of Jebel Saheiligheh.

Timber is mainly obtained from pine trees (specifically *Pinus brutia*) which are abundant particularly in Jebel Saheiligheh and in the Bassit area in the regions above 400-500 m. The only part of the coastal region of Syria which can be counted for productive pine timber is the Bassit highland (6-9 m^3 ha^{-1} yr^{-1}), particularly on the "green rocks" and the areas above 1,200 m altitude. *Quercus pseudocerris* is also exploited there and in Jebel Saheiligheh, on calcareous rock areas. Annual production reaches 3-7 m^3 ha^{-1}.

Wildlife. In the regions most influenced by human activity, fauna and wildlife barely survive. The natural forests and forestry plantations and the abundance of bush and woods in the hilly and montane zones continue to support a few large mammals such as fox, boar; hyena and (allegedly) the wolf. Deer and wild goat can also be found in secluded and isolated areas of dense bush.

Predatory birds are scarce, the most common being the falcon. The existence of vultures and eagles has been reported. The habitat of sparrows and blackbirds are open fields; while sea gulls breed in the cliffs south of Ras el-Bassit and on isolated islets and sea rocks (south of Arwad island, for example).

2.5.2. The consequences of climatic changes for natural ecosystems

Since the rate of atmospheric warming would be greater than any recent temperature fluctuations, occurring at least 15 times faster than past natural changes, the rate of consequent climate alteration may exceed the ability of species to adapt or disperse into more favourable environments. Since individual species and biocenosis are constrained by temperature ranges and by soil, water and vegetation conditions, the relative composition of animal and plant communities will inevitably be modified.

Changes in extreme temperatures, such as freezing in areas previously unaffected, or extreme high temperatures, can significantly affect the dynamics and distribution of animals and in particular insects. Many plant and animal species may become extinct.

Assessment of the impacts of temperature changes on ecosystems is hampered by a lack of detailed knowledge of present communities and individual species, and especially of the constraints that climate and other factors put on them. There are few long term observations of the response of ecosystems to altered greenhouse gases and climate conditions, outside the laboratory controlled research environment.

In the absence of such information scientists are left with very imperfect means of assessment, particularly about the secondary and combined influences of several stress factors such as the synergistic or antagonistic effects of changes in climate, fire, and air pollution on the interacting components of ecosystems (vegetation, wildlife, pests and pathogens, soil nutrients, water and air quality).

If we take into consideration that higher temperature will increase evapotranspiration and induce soil changes, it is expected that the existing ecosystems of the Syrian coastal region will be affected in the following general ways:

1. the plants will have to adapt to a new environment, and some dominant species would disappear. There will be vegetation shifts in which the plants of the plain will extend their altitudinal range into the hill areas and hilly plants will extend up to the mountains. Some of the present plant species of higher elevations may not be able to withstand higher temperature ranges and will disappear;

2. the overall impact could be negative for woods and forests, because of an increase in forest fires which would change the nature of the vegetation cover and the plant life cycles in the region;

3. in the lower coastal region higher winter-spring precipitation in association with a CO_2 enriched atmosphere, could have a generally positive effect on the existing plant life;

4. however, it is likely that significant changes would not become manifest before the average temperature has increased by 1 °C, that is perhaps after forty years. In practice ecosystems would be impacted more by the extreme events that would become more frequent along with a small rise of the mean (Wigley, 1989). In any case, during the next 3-4 decades natural vegetation and wildlife will have been much more directly affected by human activities; and

5. the temperature of the surface layer of the sea will increase, with greater evaporation and probably a salinity increase, especially in shallow areas. This will undoubtedly change some kinds of marine life forms, with a general shift towards more thermophilic species and enhancement of the migration of Red Sea species into the Mediterranean.

2.6. Managed ecosystems

2.6.1. Agriculture

2.6.1.1 Agriculture as an economic activity

Fifty per cent of the land in the coastal region (265,000 ha) is cultivated: 39.5% under dry farming, 11.5% irrigated; forests cover a further 27.7%. Agriculture is the most important economic activity in the coastal region at present and will remain so, because of its likely expansion to satisfy local and export needs. Agriculture also sustains the local food-processing industries. In 1975 agriculture employed 50-60% of the working population in the coastal region. This percentage decreased subsequently due to the development of the tertiary sector. Sixty-five plant species are commonly cultivated, 33 being of commercial importance.

The main agricultural products of the coastal region come from irrigated farming, especially citrus fruits and vegetables which are of competitive quality, as their production benefits from the moderate weather of the Mediterranean coast. Since production of these crops is much higher than consumption in the region, the produce is exported to the other parts of the country.

The main crops of the coastal region and their estimated export volumes are listed in Table 13. Demand for and prices of several products including vegetables and fruits from the coast and olive oil from other parts of Syria ensure considerable export profits.

Although citrus and olives rank first as commercial crops, wheat is still the most widespread crop because it is the staple food of the region. The Sahel Akkar plain was and still is renowned for growing wheat and other cereals. Barley is the next most important cereal grown in the region. Both are sown in dry farming areas in October and November, generally after the first rain and harvested in May.

TABLE 13

Production and consumption of various crops in the Syrian coastal region

Crop	Production (tons)	Domestic consumption (tons)	Export (tons)	Percentage exported
Orange	36,500	16,300	20,200	55 %
Lemon	10,500	5,000	5,500	52 %
Others citrus	30,500	15,000	15,500	51 %
Peanuts	17,500	5,250	12,250	70 %
Tomato	390,000	87,000	303,000	78 %
Olive	81,000	21,000	60,000	74 %
Olive oil	63,000	14,500	48,500	70 %
Cucumber	136,500	32,500	104,000	76 %
Apple	46,000	13,300	32,700	71 %
Green pepper	26,500	8,000	18,500	70 %

Tomatoes are the third most important crop, and the large production resulting from three crops a year, makes this region the most important centre of production in Syria. A large proportion of the production is processed in local factories (e.g. at Jableh). Production of tomatoes and other vegetables in the coastal plains and foothills has grown steadily over the last 25 years due to: the improved transport system; the use of fertilizers and insecticides; and, irrigation (especially in the plains). Off-season vegetables are grown in the favourable climate of the coastal plain, and as a consequence of the widespread use of greenhouses, especially in the Tartous region where they now number 14,600.

Agriculture is located mainly in the more populated coastal zone, the exception being olives which are found throughout the hills area. Agricultural activities are strongly market oriented. It is worth mentioning, that in spite of its being the main activity of the region, linkages with other economic sectors are poor and transportation, marketing and distribution networks are not well developed.

It is estimated that the present level of production could be increased at least four times, without causing problems, either for production or for the environment. The Tartous rural area has been suggested as a main site for new citrus plantations, with a concentration in the triangle Tartous-Safita-Al Sheikh Bader. In Lattakia the suggested site for agricultural expansion is the triangle Lattakia-Kordaha-Ali Haffeh. Plans for agricultural expansion in the Banias and Jableh areas have yet to be developed.

2.6.1.2 The growth conditions of some crops

Citrus. Citrus trees flower from the middle of March till the end of May. Some can withstand high temperatures, for example the grapefruit up to +48 °C, whereas the orange and mandarin would be spoiled at this temperature. The maximum temperature for citrus is 50 °C, an extreme which is never attained in the Syrian coastal region. The minimum temperature is above 12.5 °C, the optimal temperature is 20-24 °C; full ripening is reached when the temperature is higher, but then it will decline and stop at + 49 °C. It has been noticed that flowering occurs earlier if there is an average temperature of 12 °C in March.

Citrus trees grow well up to 750 metre elevation, higher if they are protected from frost and winds, and grown under conditions of good drainage. Orange needs good exposure to sunlight while in contrast grapefruit can withstand hot dry weather, but is adversely affected by direct sunlight. Lemon needs less light, but the growth is decreased in dark areas; therefore it requires regular pruning.

In regards to water, citrus trees prosper in wet weather and high humidity (optimal between 37-80%). Lemon needs a wet soil especially during the flowering period. Orange is more resistant to dryness than lemon, but it grows as well on wet soil, if available.

Citrus trees can be grown in different kinds of soils but grow best in deep or medium depth soils. Planting in heavy, poor soil may lead to root malformation and disease. With average water supply, the clay soils are the best for citrus planting.

Insects that are dangerous for citrus include, *Leerya purchasi, Ceralitus capitata,* and *Toxaptera auranti*, which are controlled by the use of phosphatic and Malathion pesticides. These pesticides have negative impacts on the environment. The main diseases are gumming and bacterial rot of the fruits (blue and green).

Olives. Suitable temperatures for olive trees are between 18 and 24 ° C; hot windless weather leads to poor fruits. The best areas for growing olives are sunny slopes up to 400 m elevation, with good soil. Light is an essential requirement, it was noticed that in sunny areas the fruits grow earlier; production of olive oil is higher and the oil is of better quality.

Olive trees can also grow in the drier areas (rainfall 200-375 mm), but its resistance to drought differs with the different varieties. It can grow without irrigation where rainfall is between 600-800 mm. If rainfall is over 1500 mm, it is affected more by the dry periods which hurt the roots, and by mycosis development. Olive trees can easily adapt to all kinds of soils, can be planted on hillsides or, on stony land and will even tolerate a little salt. It prefers the light sandy-clay soils, or deep clay soils over limestone. The trees need pruning near the fruits, best done at the beginning of spring (March, April) to manage the growth and ensure regular annual crops. Although the olive tree is a resistant species, it can be damaged by a series of cold years with severe frost. Productivity is affected by pests such as *Phoeatribus scaraboides, Pasineura olea,* and *Dacusolea spp.* In the central part of the coast productivity is lower due to the atmospheric pollution of the cement factories.

Vegetables. The most important vegetables grown in the area (broad beans, green peas, green beans, aubergines, and pumpkins) are planted in semi-protected areas with tree wind breaks and in unheated greenhouses. Conditions in greenhouses have to be carefully monitored and temperature is considered the most important factor controlling the physical, chemical, and biological aspects of production. Increased production requires maintenance of an optimum temperature since a decrease in the average temperature affects growth.

The temperature within greenhouses depends mostly on the weather but is always kept higher than in the open. Too much heat leads to water stress and wilting of the plants. To reduce the temperature and its negative consequences humidity must be increased and ventilation improved, or else varieties that can withstand higher temperatures must be selected. This has been done with some varieties of tomato and cucumber which can be grown in temperatures up to 45 ° C.

Plants need two main gases for growth: oxygen, for respiration, and CO_2 for photosynthesis. Carbon dioxide concentration in the air is 0.03%, but in greenhouses it becomes 0.01-0.005%, thus affecting photosynthesis. If CO_2 increases over 0.03% especially in good light and moderate temperature it leads to increasing average photosynthesis; if it is greater, respiration rates increase but photosynthesis decreases, resulting in interruption of plant growth.

Tobacco. Tobacco is grown in areas of the central and northern mountain and hills and in small areas of the plains (irrigated varieties). This crop is known for its sensitivity to strong winds; hot, dry wind; higher than normal rainfall and humidity; and, frost. These factors vary from one area to another. Plant diseases also affect the quality and quantity of tobacco production in some years. Blue mould (downey mildew) was the main reason for extremely low tobacco production in the region during 1964-65.

2.6.1.3 Agricultural management and development

Climatic elements play a large role in agriculture, and in many aspects of its management (e.g. soil, irrigation). The close relation of the olive tree with the Mediterranean climate is a good example of this relationship. The climate and geological factors that are favourable for agriculture in the lower coastal region of Syria are the Mediterranean climate, with mild temperature conditions and a small daily temperature range; sufficient rainfall (800-1400 mm in the higher wet areas, 500-800 mm in the lower semi-wet areas) and availability of ground water; and the presence of thick black or brown soils in the flatlands and valleys, on which fruit trees, citrus and vegetables can be profitably grown.

Soil problems. Even the best soils can present some problems for agricultural management, for instance, the red Mediterranean soil (formed in the areas where the annual rainfall is over 600 mm) has a PH 7-8, and high clay content at depth; it may be too stony and require extensive cultivation. The dark vertisols (present where rainfall is between 300-600 mm, annually) have a PH of 8-8.5; they contain much clay and become dry and crack in summer.

Other problems of soil deterioration are:

1. salinity. Salts appear at the surface due to evaporation, caused by high temperature and drought;

2. fertility deficiency, due to change of pH which may lead to fixation of nutrients, rendering the soil unsuitable for the growth of most economic crop plants;

3. sinking of the soil, due to lack of penetration, or extraction of increasing amounts of ground water, especially in the lowlands (this is the case in some low plains especially in winter, such as in Al Boka'a plain);

4. soil erosion and slumping, caused by the topographical circumstances and by heavy rainfall, or by human activities that contribute to increasing soil erosion through deforestation. The improper planting of tree wind breaks in the agricultural plains may be as environmentally unsound as deforestation. This happens in other parts of the Mediterranean region, where the natural forests are changed to exotic tree species for wood production. Forest fires are also a contributing factor to soil erosion in the artificial woodland, more than in the natural forests; and

5. man-made soil deterioration. The extensive use of fertilizers and pesticides affects the soil, and later the ground water, and soil composition.

Irrigation. The coastal zone is distinguished by good rainfall, but because of the underlying limestone geology, much of the rainwater percolates into the ground. Irrigation is unavoidable. The Al Seen spring and river irrigation system which serves an area of 90 km^2 operates through five pumping stations. Other irrigation projects have been based on the construction of reservoirs at Balouran, All Haffeh, Kanjara Sakiat Sadek, Bait Kassir, Bekrama and Al Khalifa. The capacity of all these reservoirs is 24.9 million cubic metres in Lattakia province; and 30 million cubic metres in Tartous province. Other dams are under construction.

According to the statistics of 1988, the irrigated area in the coastal zone is estimated to be 480 square km; 260 km^2 in Lattakia, and 220 km^2 in Tartous province. In addition to the Al Seen network, the other main irrigation networks are the Al Nahir, Al Kabir irrigation system in Lattakia which irrigates an area of 157.2 km^2. Its water sources are the Al Nahir, Al Kabir, Al Shamali, and Balouran Al Sonoubar reservoirs. The Akkar irrigation network, serves an area of 55.4 km^2 in Tartous with water from the Al Khalifa and Al Abrash reservoirs.

Farmers use water for irrigation from different sources: lakes, reservoirs, rivers, streams, and ground water. Water distribution is through different systems, but mainly by plastic piping. New facilities have been constructed together with dams, that will replace older systems.

The problems of irrigation and water distribution can be summarized as follows:

- the quality of irrigation water in most cases is not of acceptable standard;
- the stealing of drinking water from water supply networks is widespread;
- the lack of protection of lakes and irrigation networks against illegal use;
- the over-pumping from wells, that has resulted in the drying of some (north of Lattakia, island of Arwad, south of Tartous) and in salinization of others due to sea water intrusion into the fresh ground water; and
- the Al Seen spring is subject to pollution by coliforms and from the use of chemicals in agriculture.

For the expansion of agricultural production, which has already started through citrus plantations and the use of greenhouses, priority must be given to completing the irrigation projects which are under construction or planned.

The present reservoir capacity of 28 million cubic metres which is used for irrigation today, can be increased to more than 290 million cubic metres following completion of all irrigation projects. The water supply in Tartous area will increase from 11% to 31%.

Agricultural development requires the strengthening of irrigation systems and the promotion of pricing policies. Positive effects will be on incomes, export, migration, self sufficiency in agriculture, and in creating employment. Agriculture needs fixed labour in the small settlements, and promotes jobs in the service sector (production, treatment, marketing, provision of agricultural materials such as fertilizers, and the maintenance of agricultural machines).

2.6.2. Fisheries

The fish catch in the inland lakes of the Syrian coastal zone (The Khalifah, Tishreen, Al Sounaouber, Balouran and Kanjara reservoirs), is limited, being estimated at about 30-50 tons annually. Carp is the main commercial species. The total marine fish catch in 1990 was 1,951 tons, and in 1991, 1,406 tons. The main commercial species are; pelagic sardines, Palmida, and tuna and demersal species such as Sultan Ibrahim, Jarbida, Shrimps, Fredi, Anytas Mosa, Milan, Henkis, Ghabous, Buri, Safrneh, Shkarmei.

There are three large fishing boats that make extended (20-30 day) trips outside Syria and which are forbidden to fish in in-shore waters. There are more than 95 boats in the inland lakes and 1,145 wooden boats fishing the coastal areas according to 1990 statistics. Fish is mostly consumed in the coastal region, Damascus, and Aleppo. There is no export market.

There are government plans to develop fishing and research in fisheries to identify the available species and estimate the average annual yield in order to organise the fishing fleet.

In regard to the influence of temperature, fish can be divided into three groups:

- cold water species with preferred temperatures between 10 and 12 °C;
- warm water species (temperature preference of 33 °C); and
- moderate temperature species.

The differences in temperatures are small in the coastal water and the difference in temperatures between summer and winter are slight. Temperature at depths of 12 m in the cold period is 19 °C; in the warmest period 23 °C. At the surface, temperatures range from 16 °C to 29 °C. At greater depth, the difference in temperature is smaller.

To elucidate the impact of different temperatures on fish, we can take the example of the Sallour. The optimal temperature for this species is between 24-26 °C. If there is a slight rise of temperature, the fish will be more active, but if there is a greater increase the fish will die. Similarly changes will occur if the temperature drops.

2.6.3. Aquaculture

The only aquaculture establishment in the coastal region of Syria is the Al Seen Masub farm, for fish hatching and raising. It is located at the mouth of the Al Seen river near Banias.

2.6.4. Sylviculture

Afforestation needs to be based on sound knowledge of the environmental requirements of forests in order to get the best production of timber. In afforestation programmes the choice of tree species depends on the forest use: for wood production; for protection against soil erosion; for wind protection; or, for general purposes.

The state is carrying out a reforestation programme in the coastal region for the following purpose:

1. restoring plant cover in burned areas, in order to protect the soil from erosion and landslides under the influence of heavy rainfall;

2. planting fir trees instead of oak to produce wood; and

3. planting some areas with mixed fruit and pine trees for wood and fruit production.

In the municipality of Lattakia 6,293,000 pine trees were planted in different sites between the years 1976 and 1992, but 1,367,000 plants were burned. Although 58,000 trees planted before 1976 have reached the fruiting age, production is low because of the dense planting.

Chestnut trees were planted between 1990 and 1991 (263,000), for fruit and timber production and for soil protection. Other species such as *Pinus brutia*, kina, cypress, *Acacia cyanophyla* and *Robinia* have also been planted.

In Lattakia, afforestation with pine has been in mountain areas at various localities: Jableh, Kordaha, Ein Eldo, Jonjania, Bichili, Bolat, Al Moa'laka, Kordaha, Zeghrin, Al Kasab, Al Basit, Kasab, Om Al Touyour.

In the municipality of Tartous the number of pine trees which were planted in the period 1976-1992 was 2,300,000. Other species such as *Pinus brutia*, chestnut, kina, *Acacia cyanophila*, *Robinia,* and cypress were also planted. Afforestation in Tartous has been carried out in many different areas: Sha'ara Gharbia, Hammam Wasel, Al Qadmous, Kharbat Makkar, Shkaret Al Bahri, Doir Tali'i, Al Nabi Saleh, Alsawari, Al Rakmah, Al Inazza.

2.6.5. The implications of climatic changes for managed ecosystems

2.6.5.1 Impacts on agriculture

Estimating the effects of changing climate on agriculture is still rather problematic, not only because the features of future climate in the eastern Mediterranean region are quite uncertain, but also because the response of the different crops plants; weeds and pests, to changed soil moisture levels, temperature, and higher CO_2 in the atmosphere are uncertain. The present scenarios (section 2.1) suggest changes of both average temperature and rainfall; of relative humidity and of evaporation which would become effective by 2030 (Table 1).

Of importance for agriculture would be a longer growing season, possibly with less water in summer and altered soil conditions. How would such changes affect the present crop type and yield in the coastal region ? Our basic knowledge is still inadequate; as stated by Parry (1989) "At present it is merely possible to consider, in a very simple manner, the effect that future climatic changes would have on present-day agriculture, if it were to occur now, under present technology, management and trade structures."

The greatest risk for agriculture derives from the combination of elevated temperatures and droughts (or floods), due to intermittent precipitation and to greater inter-annual fluctuations. Relatively small changes in seasonal distribution of rainfall could have disproportionately large effects. Serious impacts would result from decreased soil water in summer and winter, and in general from changes in the periods of growth, when adequate moisture content is necessary.

Change of average temperature would include: a reduction in winter chilling (vernalization), the low temperature period in winter required by many temperate crops and fruit trees. It is estimated that a 1 °C increase in winter temperature could reduce effective winter chilling by 10-30%. Increased temperatures would lead to insect invasion earlier during the growing season and to the easier spread of diseases, because of the increase in disease vectors.

The changed climate conditions, to warmer, more humid conditions would be beneficial for citrus fruits and to some extent for olive trees, and in general for growing vegetables, so long as the water supply remains adequate.

Higher CO_2 concentrations in the air are generally thought to be beneficial for agriculture, although this is still not adequately established, especially outside experiments in greenhouses or growth chambers. The main distinction is between so-called C_3 and C_4 plants (a classification based on the primary enzymes involved in photosynthetic carbon fixation). Wheat barley and potatoes are C_3 plants, that respond positively to higher CO_2 concentrations. In controlled environment studies, with optimal temperature, nutrients and moisture, the yield increase for doubled CO_2 in C_3 cereals (wheat, rice and barley) and for sunflower could be as much as 36% but only 0-10% for C_4 plants (Parry, 1989; Parry and Jiachen, 1990). These plants are more "limited" than C_4 plants and thus respond more positively to higher CO_2 concentrations. This phenomenon has been demonstrated many times in experiments conducted in controlled greenhouses or growth chambers.

The C_3 crops of temperate-subtropical regions could also benefit from reduced weed infestation, since many common crop weeds are C_4 plants. There would also be an increase in water use efficiency by the plants, because transpiration would be reduced by 23-40% due to reduced stomatal aperture opening.

In practice the impacts of CO_2 enrichment on actual yields of common crops is problematic; overall it could be positive, although the nitrogen content of plants is likely to decrease as the carbon content increases (at least in C_3 plants) and thus there might be a need for greater use of fertilisers (with its consequences for soil deterioration and water pollution).

2.6.5.2 Impacts on sylviculture

Although plants and trees are adaptable, each species has its ultimate limits. Higher altitude forests would be affected by the reduction in length of the cold resting period, they would be more susceptible to physical stress, to infestation of insects and diseases, to changes in forest soils, and to forest fires.

2.6.5.3 Impacts on fisheries

Unless there are significant negative alterations in the food chain and in some ecosystems that are vital to the present commercial species, impacts are unlikely to be significant. In general, fisheries could benefit from increased temperature (Kawasaki, 1990).

2.7. Industry and energy

2.7.1. Industries

The strong industrial and power supply base of the coastal region, namely the oil refinery at Banias (6 million ton per year, 50% of the national production), the oil-fired electricity station south of Banias (20% of the country's installed capacity) and the Tartous cement factory (2 million ton per year representing 50% of national output) serve needs much larger than those of the coastal region (Table 14). This function is supported by the ports of Lattakia and Tartous (19 million tons of goods handled in 1984), and by the railway and excellent road network which connect the coastal region with the rest of the country.

In addition, there are two petroleum terminals, one in Banias to export the products of the Banias refinery, and another in Tartous to export products from the Homs refinery, as well as those of manufacturing industries.

The manufacturing sector is experiencing various problems and its development has been less successful than that of other sectors. Lattakia is an under-developed centre for manufacturing activity (wood panelling, electric motors, textiles, gypsum, marble and tobacco factory, etc) which has increased the attractiveness of the city and its surroundings, drawing population from the hinterland.

Although the manufacturing industries (all in the public sector) face production problems (the main one being the shortage of raw materials) their potential is considerable.

TABLE 14

Industrial Production in Syria

Indicator	Coastal region	Syria	Share of the coastal region
1. Industrial production (87)	4,222 MSP (gross) 1,400 MSP (net)	42,218 MSP (gross) 13,7 MSP (net)	10 % 10 %
2. Cement production capacity	2,1 MT	5,6 MT	38 %
3. Oil refining cap.	2,0 MT	12,0 MT	50 %
4. Electricity generation cap.	715 MW	2067 MW	35 %
5. Domestic water supply	165,000 MG	1,966,000 MG	8 %
6. Domestic water supply subscribers	110,000	732,000	15 %

MSP = million Syrian Pounds
MG = million gallons
MT = million tons
MW = million watts

2.7.2. Energy

The system of energy infrastructure (Figure 32) is analyzed at two levels, energy production and energy consumption. At a regional level, there are two main sources of electrical energy.

The Banias station contains four units of 170 MWH each, consuming about 1,600 tons of fuel oil per day, which contains 3.6% sulphur by weight. There is also a gas turbine unit with a 30 MWH capacity ready to start operating.

The units use sea water for cooling. The electricity production of the Banias station represents 35-38% of all Syrian production and about 30% of the total energy requirement.

The Lattakia station has two gas turbines of 20 MWH each (heavy oil) for use in peak consumption periods. There is also a station on Arwad for local supply; and two movable reserve units (5 MWH each), one in Lattakia, the other in Tartous.

The region is connected to the national grid and to Lebanon by high-voltage electric lines (230 KV). The main transformer stations (230/66 KV) are situated in Lattakia, Tartous and Banias. There are 9 second-order (66/20 KV) stations in Banias and north of Lattakia, (Qardaha - Haffeh, Al Seen, Tishreen University, Banias, Lattakia, Ras el Basit, Qardaha - Lattakia, Banias-Qardaha). In addition there are 2,656 (20/0.4 KV) transformer sub-stations, 1,673 in the Lattakia mohafaza, and 983 in the Tartous mohafaza.

In the coastal region almost all settlements are supplied with electricity. According to some sources of information as much as 96% of the population of Tartous province and 99% of the Lattakia population have electricity.

The share of Lattakia and Tartous mohafaza in the national energy consumption was 4.42% and 6.00% respectively in 1988. In the coastal region electricity consumption amounted to 10.42% of the country's total consumption which corresponds to the share of the region's population in the country's total. The high percentage of Tartous mohafaza can be attributed to its industries, particularly the oil refinery and cement factory which are the heaviest consumers of energy in the region.

The government encourages the use of renewable energy, in particular, of solar energy. This technique is applied at Tishreen University, as a government project.

2.7.3. The impact of climate change on industry and energy

Climatic changes could have far reaching consequences for industries, not only locally, but as a result of aggregate impacts on industries worldwide. The effects can be direct and indirect. The direct impacts of climate change are likely to vary considerably between the different industrial sectors. Generally, the more weather sensitive industries on a historical basis would appear to be more vulnerable in a rapidly warming world.

The most significant likely indirect impact of climate change on the industrial sector are public policies designed to restrain emission of greenhouse gases, which could enhance opportunities for energy-efficient technologies, while penalizing those that emit large quantities of such gases. Among the greatest potential impacts on the manufacturing sector may be requirements to increase the efficiency of manufacturing processes and to reduce energy consumption and greenhouse gas emissions. One of the industries that may be particularly affected by such response strategies, is the cement industry.

If one considers the effects of warming on the energy use patterns of today, one could expect a greater demand for summer air conditioning, but a decreasing demand for winter heating. On balance, there would be a definite increase in electricity consumption.

Energy consumption will certainly increase in the next 2-3 decades due to greater numbers of private cars, industrial consumption and urban uses. At present most power generation relies on fuel oil, which causes greater emissions of CO_2 to the atmosphere than some other fuel types.

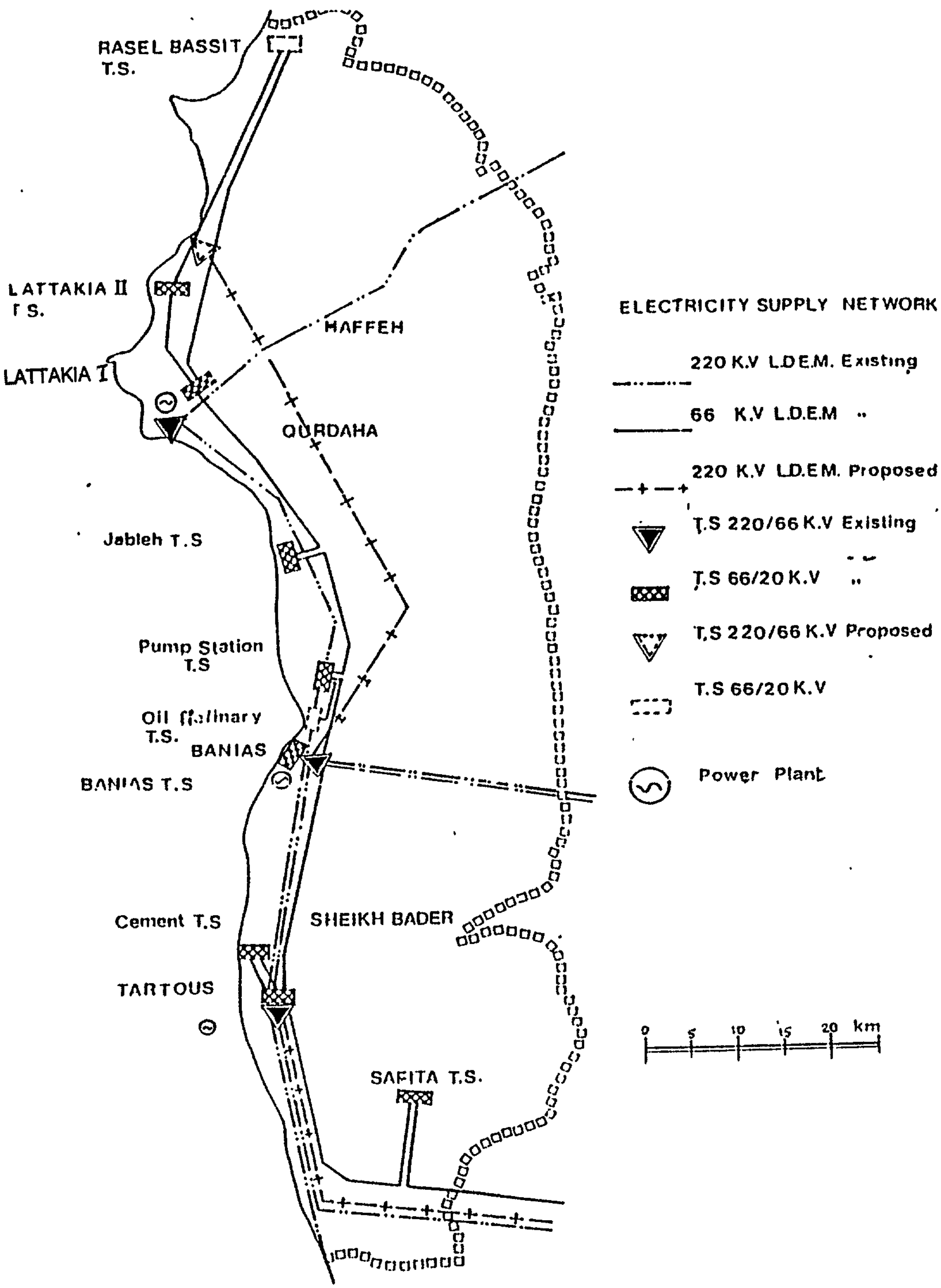

Figure 32 - System of energy infrastructure

Urban heat and gas emissions will need to be controlled, to counteract the increasing urban temperature in a warmer climate. Demands for indoor cooling could be met by improved building techniques that allow for greater indoor ventilation.

Impacts on energy use by 2050 (let alone 2100) cannot be evaluated, due to the large degree of uncertainty regarding development and energy sources. Unless new and cheaper sources of energy become effective a rise in the price of energy production (due to increasing prices of petroleum) could curb energy use.

2.8. Tourism

2.8.1. Present and future situation

The Syrian coastal region, like other parts of the Mediterranean shores, contains many tourist attractions such as sandy beaches, scenery, and archaeological sites. Figure 33 provides data on the distribution of potential tourist attractions in the Syrian coastal region. At present tourism is not an important activity and contributes only a very small share to the economy of the region. Visitors to the coastal region are mainly Syrians (85%); foreign tourists come equally from Arab and other countries (8.5 and 6 % respectively) whereas in the rest of Syria, Arab visitors are by far the most predominant group (Tables 15, 16, 17).

TABLE 15

Origin and destination of visitors to Syria

Region	Arab tourists 1990	Foreign tourists 1990	Total of both	Syrian tourists 1990
Lattakia	10,423	16,205	26,628	150,529
Tartous	4,596	3,799	8,395	53,442
Coastal region	15,019	20,004	35,023	203,971
Syria	281,807	27,995	309,802	1,245,749

Non-arab foreign tourists mostly visit the archaeological sites and organised package tours to beach resorts are still on a small scale. The Syrian coast at present is the main destination for tourists from the Middle East region for summer recreation, on account of bathing and the milder Mediterranean weather. The high tourist season lasts from June to the end of September (Tables 16 and 17).

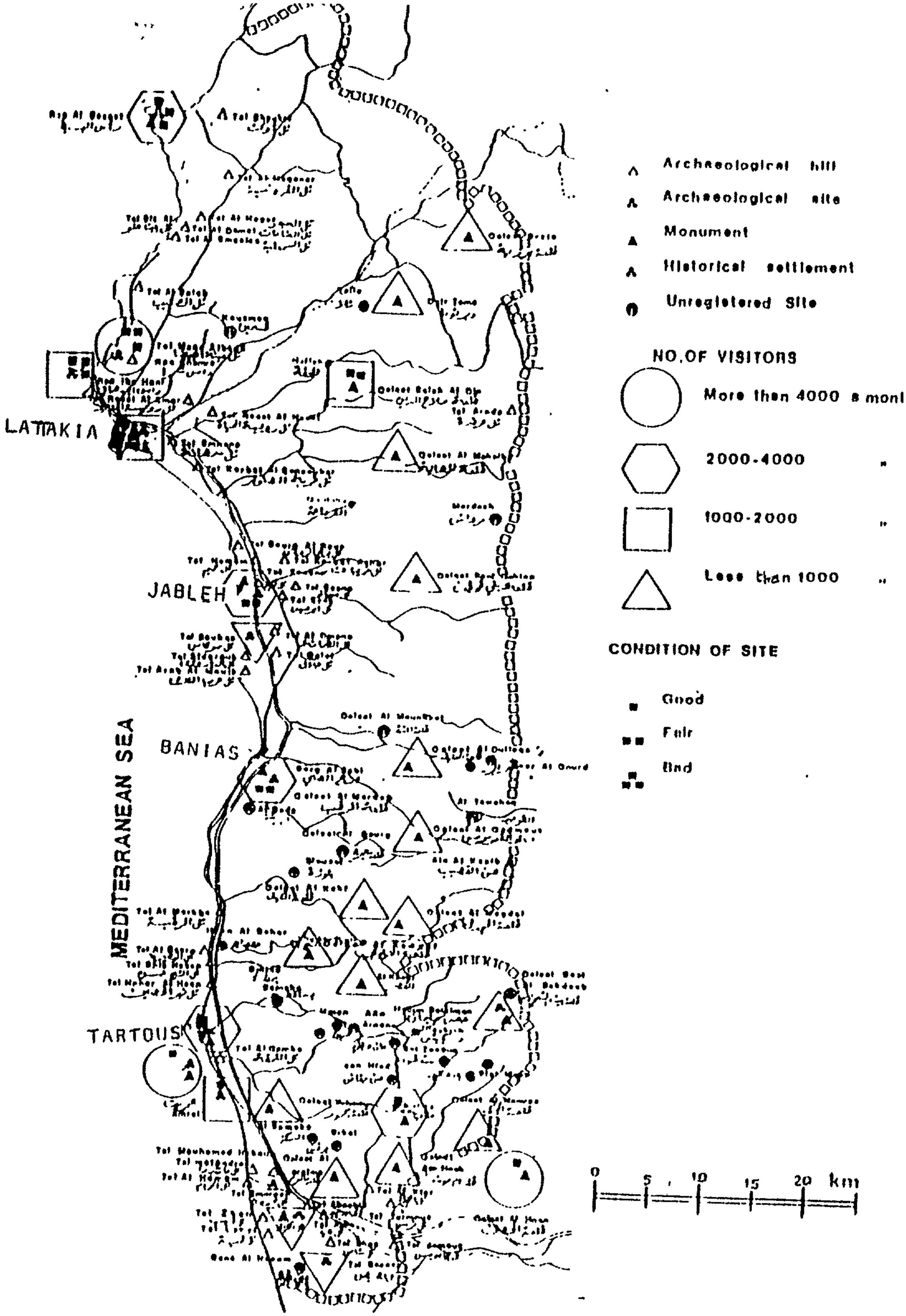

Figure 33 - Tourist centres and visitor numbers in the Syrian coastal region

TABLE 16

Nights spent by Syrian tourists, by month and Mohafaza in 1991

Month	Lattakia	Tartous	Coastal region
January	10,786	3,669	2,817
February	10,082	3,558	2,195
March	11,594	4,061	1,994
April	15,173	5,018	2,994
May	11,978	4,231	2,834
June	24,403	6,850	4,151
July	25,384	1,794	5,193
August	**58,237**	**32,215**	**9,363**
September	40,617	9,682	5,000
October	13,647	4,884	3,485
November	12,601	4,155	3,034
December	9,470	3,813	2,015
Total	**243,972**	**83,930**	**45,075**

TABLE 17

Nights spent by Arab and foreign tourists
(source: Statistical Abstract of Syria, 1991)

Month	Arab tourists		Foreign tourists	
	Lattakia	Tartous	Lattakia	Tartous
January	1,592	1,225	399	245
February	1,626	569	237	147
March	1,189	805	657	388
April	1,934	1,060	1,020	253
May	2,139	695	1,790	228
June	2,836	1,315	1,333	308
July	3,804	1,389	1,141	491
August	6,832	2,531	2,690	479
September	4,308	692	1,867	519
October	2,213	1,172	2,950	423
November	1,739	1,295	282	266
December	1,129	886	3,206	346
Total	**31,441**	**13,334**	**17,572**	**4,093**

Lattakia province hosts the majority of tourists because it has several good sandy beaches, a number of archaeological sites including Ras Shamra, Salah Al Din Castle and a large number of hotels and facilities. In 1990 there were 96 hotels and motels in the coastal region (30 in Tartous province) offering 5,776 beds. Over 4,000 beds were in hotels classified as "international establishments", entirely in the Lattakia Province.

Although tourism is still a minor economic activity, it is likely that it will become important in the future, and that it will attract capital investment. The Ministry of Tourism is fostering an employment programme with projects in the coastal region over the next 20 years (Table 18).

TABLE 18

Proposed tourist developments (source: Ministry of Tourism)

Project name	Proposed employment programme	Capacity
1. Tourist settlements, in Ras-Al-Basit	Hotels, chalets, villas, tourist camps, commercial centres, restaurants	2,640 beds
2. Tourist complex in U'm Al Touior	Hotels, chalets, villas, tourist camps, restaurants, fishing harbour, sport and commercial centres	6,600 beds
3. Tourist complex in Wadi Qandeel	Hotels, chalets, villas, restaurants, fishing harbours, commercial an sport centres	8,400 beds
4. Tourist city in Ibn Hani	Hotels, motels, chalets, restaurants, cafeteria and cinema in open air, recreational, sport and commercial centres	3,500 beds
5. Tourist complex in Al Sounaouber region	Hotels, chalets, villas, picnic and fishing harbours, playgrounds, restaurants and commercial centres	4,000 beds
6. Tourist complex in Arwad island	Hotels, restaurants, swimming pool, night club, marine sport	300 beds

The following facilities are under construction at present:

1. Al Qardaha hotel: super class, with 2,500 beds;
2. Mashta Al Helo spa project: super class, with 300 beds;
3. International Banias camp: commercial centres, restaurants, etc;
4. Amrit project, south of Tartous: a tourist complex with 2,000 beds; and
5. Camps project near Amrit with 12,000 beds.

Communications and services are adequate, with a good road network and railways, but there are some problems affecting tourism such as periodic electricity cuts and water supply shortages, in addition to the problem of mosquitoes near the Mediterranean shores. Air and sea pollution are a problem in the Tartous region and the Ministry of Tourism has budgeted for a plan to clean the shore which was due to begin in the summer of 1992.

2.8.2. Impact of climatic changes and sea level rise on tourism

Only a general statement can be made about the possible consequence of climate changes, since both temperature and sea level increases could become significant only by 2030-2040. The future state of the tourist industry at that time is totally unpredictable, depending as it does on many factors other than climate. What is certain is that in the next 10-20 years the Syrian coast will be much more occupied and exploited for summer tourism than it is today.

1. The rise in temperature should not adversely affect Syrian and Middle eastern tourism because the main attraction for these tourists is the moderate coastal Mediterranean temperature compared to the surrounding regions. A difference which will persist. Nevertheless, planning for future tourist development should take into account climate change scenarios, especially in regard to freshwater availability, pollution and health conditions.

2. On the other hand, a rise in sea level of 15-20 cm (2030-2050) would have considerable impacts on tourist beaches and facilities (as they are at present) because of their proximity to the shoreline. Beaches might remain stable during this period, but for the same reason, erosion problems could become significant with a rise of more than 20 cm after 2050; then, loss of beaches would become a serious problem.

2.9. Transportation and services

2.9.1. The present situation

Roads. The road network of the coastal region is one of its most valuable man-made resources (Figure 34). The coastal motorway stretches along the coast connecting the main towns with the interior of Syria (Homs). Its northern extension (Lattakia, Aleppo and the link to the Turkish border) has not yet been built. Primary roads run from: Banias to Hamma; Lattakia to Aleppo; Lattakia to Al-Haffeh to Slenfeh; Lattakia to Al Qurdaha; Lattakia to Khan Ajoz to Kassab.

Many roads link the coast with the hinterland of the region, providing efficient connection between the coastal cities and the rural areas.

Railways. The railway network of the Syrian coastal region consists of two transverse links to the interior (Lattakia-Aleppo and Tartous-Homs), and one coastal line (Lattakia-Tartous). The coastal railway runs parallel to the motorway; its embankment is to some extent a hindrance to communications between the coast and the immediate hinterland.

Harbours. Lattakia and Tartous are the main harbours. The ports of Arwad, Jableh and Banias have no special commercial significance as they are mainly fishery and service ports. The Tartous oil terminal situated 2.5 km north of the port, is specialized in handling Syrian oil exports, while the Banias oil terminal is the main export-import terminal for the white and black derivatives. It can handle four 120,000 ton tankers at one time.

The capacity of the port of Lattakia amounts to 6 million tons a year, but there is an ongoing project to increase its capacity. The port of Tartous is a new and modern structure situated at the northern edge of the city's waterfront with enough room to enlarge its service and storage area northward, under an ongoing project.

The port contains a phosphate terminal with a 2.4 million ton mineral silo and 100,000 ton grain silo. There is a plan to transfer the phosphate terminal to the northern zone of Banias along the coast. The Banias oil terminal does not occupy much land except for the tanks of the nearby oil refinery. It could be expected that the presence of the refinery will stimulate the development of related secondary industries and induce growth of the commercial areas.

Airports. Lattakia airport is located in the northern part of the Jableh plain, and can handle as many as 500,000 passengers a year.

Other Transportation. There are some ferry lines connecting Lattakia with other Mediterranean ports in Greece and Cyprus. There are a taxi boats between Tartous and Arwad island, and irregular coastal cargo or passenger ship lines fostered by the development of tourism. New excursion lines can be expected to follow the existing ones (Jableh, Banias) and will involve construction of new tourist ports (Ra'as al bassit, Hamidiyeh).

There is a network of pipelines for crude oil and petroleum products.

2.9.2. The consequences of climatic changes

Conditions and manner of the rainfall, and soil conditions would affect road construction, especially in hilly areas. Infra-structural facilities would be affected by a wide range of indirect impacts (section 2.7).

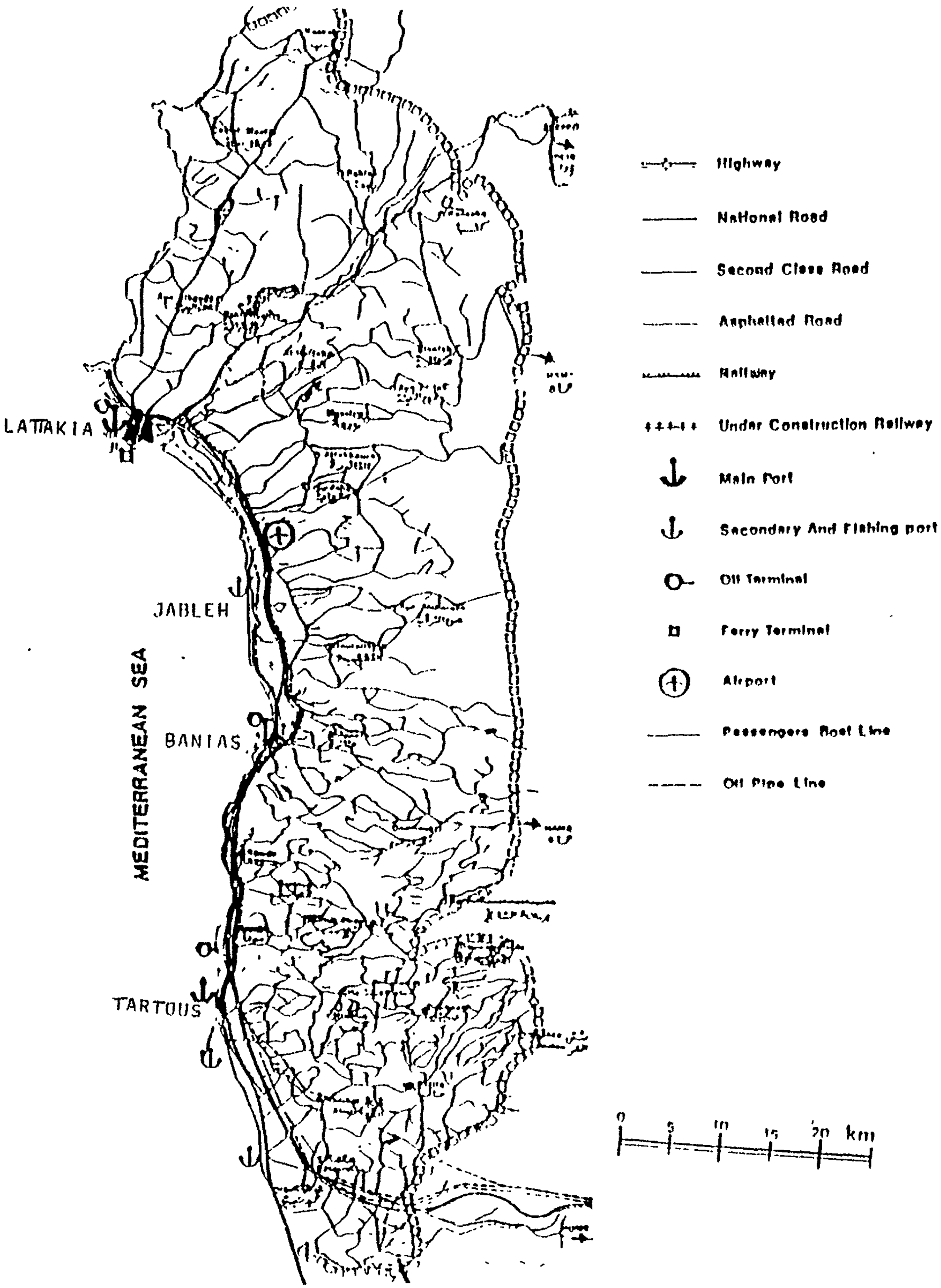

Figure 34 - Communications and transport networks in the Syrian coastal region

2.10. The consequences of climatic changes for health and sanitation

Global climate change may lead directly to greater incidence of disease and mortality rates, as a consequence of temperature increase and through increased ultraviolet radiation. Global climate change is likely to lead to a more unhealthy human environment through affects on ecosystems leading to more mosquitoes and pests in summer, and alteration to human hazards such as parasites and chemical pollutants and by producing changes in the quality and quantity of water.

2.11. Population and settlement

2.11.1. The present situation

The Coastal Region is divided into two "mohafazas" (provinces): Lattakia and Tartous. Population is urban and rural but most people live near the coast in the main cities, such as Lattakia, Jableh, Banias, and Tartous (Table 19).

TABLE 19

Coastal urban and rural population by Mohafaza (Province) (source: Statistical Abstract of Syria, 1991)

Mohafaza	Urban	Rural	Total
Lattakia	328,000	430,000	758,000
Tartous	137,000	486,000	623,000
Coastal region	465,000	916,000	1,381,000
Syria	6,335,000	6,194,000	12,529,000

Population density in the coastal region ranges from 119 to 338 km $^{-2}$. According to Table 20 outside the city of Lattakia the highest densities are in the mantikas of Jableh, Safita and Driekeesh. Figure 35 shows the regional distribution of population density, and population changes from 1970 to 1990 are indicated in Table 21.

TABLE 20

Population Density, km $^{-2}$ over the period 1960 to 1988

Mantika	Area km ^{2}	1960	1970	1981	1988
Lattakia	901	154	232	338	-
Jableh	460	127	191	283	-
Haffeh	539	93	100	119	-
Qardaha	400	81	95	142	-
Lattakia Mohafaza	2,300	122	169	241	300

Mantika	Area km ^{2}	1960	1970	1980	1988
Tartous	571	127	177	271	-
Banias	584	94	133	191	-
Driekeesh	188	143	185	238	-
Safita	346	136	180	260	-
Sheikh Bader	201	86	731	190	-
Tartous Mohafaza	1,890	116	160	235	297

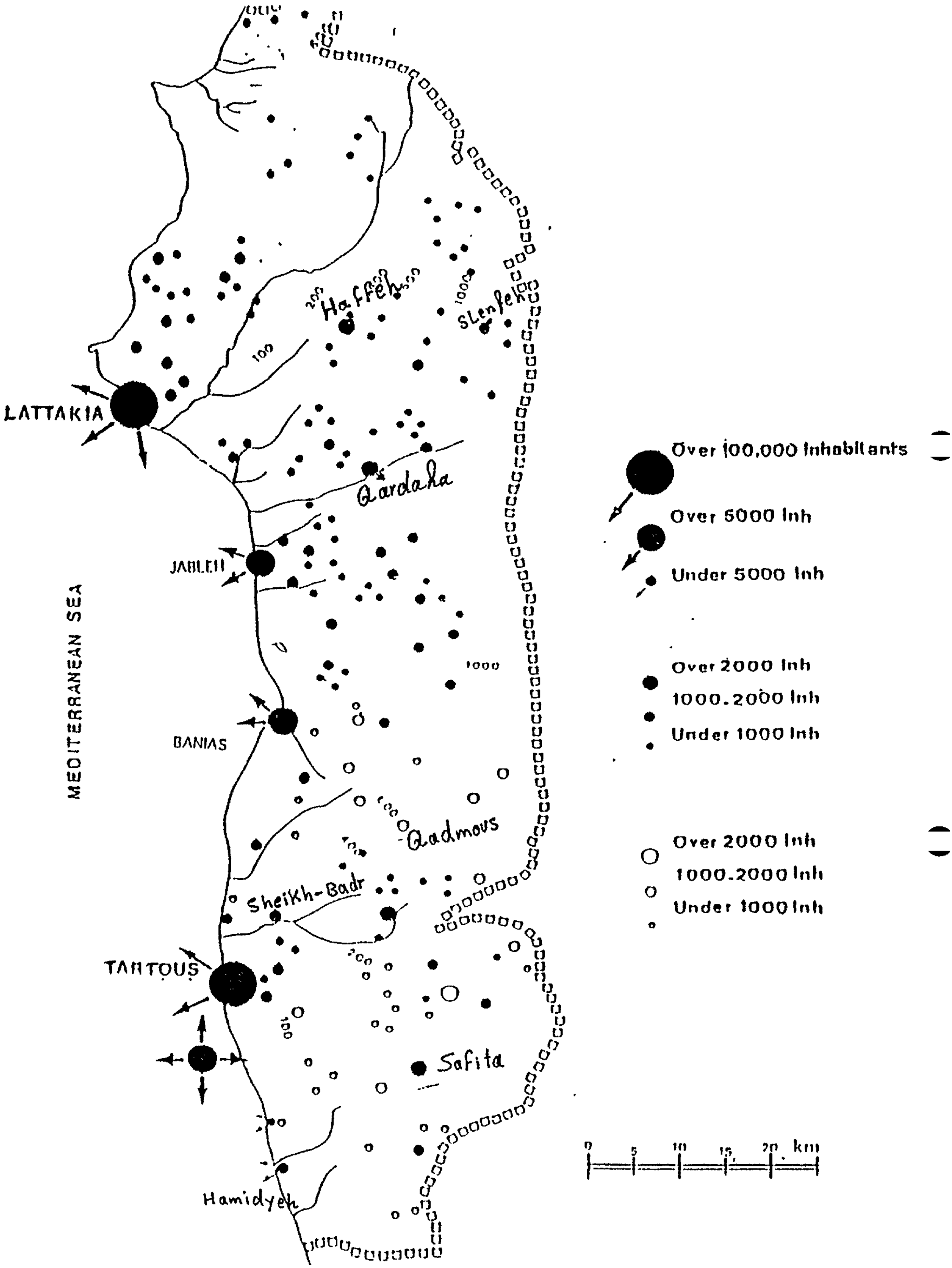

Figure 35 - Population density and distribution in the Syrian coastal region

TABLE 21

Total population of Syria and of the coastal region between 1970 and 1990

Year	Coastal region	Syria
1970	690,000	6,257,000
1981	994,000	9,046,000
1990	7,293,000	12,116,000

The high increase in total population is the result of the natural growth rate which is not only typical of the coastal region, but also of all other areas in Syria, as shown by the data in Tables 21 and 22.

TABLE 22

Population rate of growth (% per annum) over the period 1960 to 1988

Area	1960-70	1970-81	1960-81	1981-88
Lattakia	3.3	3.3	3.3	3.2
Tartous	3.3	3.6	3.4	3.4
Coastal region	3.3	3.4	3.4	3.3
Syria	3.3	3.3	3.3	3.4

At the level of "nahias" (communes), not a single one showed a decrease in total population during the 1960-1981 period. A lower level of population growth in some nahias could be attributed to internal migration. The highlands of the region are characterized by scarcity of natural resources, a lower level of economic development and by poor communications. These have been the main causes of internal migration. The coastal region is the most densely populated region in Syria.

Population changes from 1970 and 1990 are indicated in Table 21. It is expected that the population in the coastal region will reach about two million by the year 2000, with a density of about 470 people km^{-2}. But it must be stressed that the existing area is not sufficient for human development in the future. This will constitute a real problem for long-term planning in the area.

In the Lattakia province, Lattakia, Qardaha and Jableh are the centres of the most important activities (Figure 35); there is a development discrepancy between the northern and southern parts of the province. The Tartous mohafaza has a more balanced settlement pattern, although Tartous is the centre of economic activities. There are many development resources and there are 523 towns and villages evenly distributed throughout the area. Safita is a clear example of the settlement style. The Hamidiyeh "mantika" should be identified as one for potential rural growth, capable of enhancing the economic and physical balance of Tartous.

2.11.2. The consequences of climatic changes

Climate changes, especially the increase in temperature, should cause no direct impacts on population in the coastal region, because they will be gradually exposed to the increasing temperature and will become adapted to it. Social and economic activities will be affected.

The rise in temperature of 1.8° C (by 2050) and the attendant increase in relative humidity could cause a considerable increase in requirements for air conditioning, so there will be a need for increased electricity production and gas consumption. Taking into account the inevitable future of oil prices, there will be a need to search for other sources of energy.

The expected increase in population in the coastal region due to the high birth rates, and migration will result in food shortages since demand will exceed production capacity. There is a need to establish scenarios for planning in the face of such problems.

The rise in temperatures and the increase in population would most likely lead to a further rapid depletion of water resources. More local dams would be required to alleviate this problem which will further deplete groundwater resources. The rise in temperature and the population growth will necessitate the development of new energy and water sources.

In terms of the likely impacts of climate change on human health; global climate change may lead to direct changes in morbidity and mortality through temperature related stress and through ultraviolet radiation increases. Global climate change is likely to affect the ecosystems and alter human hazards such as parasites and chemical pollutants and to affect human health through changes in the quality and quantity of water.

3. SYNTHESIS OF FINDINGS

3.1. The present situation

1. The main factors which characterize the climate of the coastal region of Syria are the interplay between the western depressions, the SW khamessin winds and the E and NE winds, and the influence of the Mediterranean Sea and the coastal mountains. Temperature is relatively moderate; fairly cold in winter, especially in the mountains (with snowfalls), warm in summer with high relative humidity and evaporation. Precipitation events are related to Mediterranean cyclones.

2. Rainfall tends to be torrential, with important surface runoff and loss to underground reservoirs. Many areas are subject to soil erosion, some to a high degree.

3. The coastline is geologically stable, without subsidence, but beaches are (with some important exceptions) narrow and with a low gradient.

4. Population density is high; industry, agriculture, and forestry are the economic base of the coastal region, and are also of national importance. Tourism and use of the coast for recreation is not yet an important economic activity.

5. The considerable economic growth and social changes of the last 20 years have led to increasing occupation of the 10 km wide coastal zone, with urbanisation, and progressive use of the coast for summer leisure and tourism. This trend is expected to continue.

6. Environmental problems for society and economy that are of natural origin include soil erosion and the impacts of adverse weather conditions, such as damage caused by droughts, spring frosts, hail, strong dry winds, interannual variation in precipitation, and other meteorological events, affecting agriculture.

7. Other environmental problems of anthropogenic origin include:

   (a) soil deterioration due to excessive use, and in the mountains to deforestation;

   (b) water pollution, due to inadequate waste disposal systems (lack of waste outfalls to sea, waste products of olive presses); and to local industrial, air and water pollution;

   (c) deforestation due to cutting, grazing, replacement of natural vegetation by crops, expansion of settlements and agriculture, and other operations; and

   (d) urbanisation, a consequence of population growth and of coastal tourism, causing over-crowding, noise, and adverse microclimate conditions.

8. The Task Team has established that there are considerable gaps in data on many aspects of the different systems of the region, such as on physical oceanography; natural ecosystems; and the morphology and dynamics of beaches. Socio-economic projections are also not adequate for climate change impact analysis.

3.2. Major expected changes and their impacts

At present the ability to produce an accurate regional forecast of climatic conditions, decades, years or even months into the future is still quite poor (Wigley and Raper, 1992); the IPCC 1990 and 1992 reviews have stressed the inadequacy of present information and the lack of specific studies. For instance, we cannot forecast future water demands, as forecasts depend on estimates of the regional social and economic conditions likely to exist contemporaneously with a future changed climate, and on an increased understanding of relations between climate variability and hydrological response.

Apart from the adopted scenarios of temperature and precipitation based on the East Anglia study (Annex 1, Table 1) scenarios of the state of the climate of NW Syria during the next century remain vague. One is forced to make multiple hypotheses that take into account the wide range of temperature, rainfall and evaporation possibilities.

1. The climate change scenarios are:

   (a) temperatures could increase from as little as 0.8 to 1.2 °C in the lowlands, 1 - 1.6 °C in the mountains (low predictions), to as much as 2 - 6° C in the worst case scenarios. The summer and autumn increase would be larger than those in the winter and spring, and in general the range between the suggested extreme values (absolute maxima and minima) may be greater than today;

   (b) winter and spring precipitation could increase appreciably (3.6 - 10%) especially in the coastal lowlands, while rainfall in the autumn (and the rare summer rain) could virtually disappear. It should be noted however, that the level of confidence in these rainfall predictions is considered to be low;

   (c) humidity would not increase much (0-3%) in the coastal area during the next 100 years, but considerably more in the mountains. The average potential evaporation and evapotranspiration could increase by 8-15% by 2030 and by 15-20% by 2100. The greatest increases would be in summer and autumn;

   (d) it is believed that interannual variations and the frequency of extreme events would increase; and

   (e) the general pattern of circulation may remain unchanged in regard to the prevailing winds of today, but the SW winds could become more important.

2. In consideration of the predicted increase in temperature by 2030; that precipitation could be either somewhat less or, similar to that of today; that sea level could be no more than 20 cm higher, even by 2050; it is concluded that during the next 30-40 years the impact of non-climatic factors (population increase, present development plans) on the natural environment and society would most probably far exceed the direct impacts of any change of climate.

   Nevertheless changes in climate conditions may contribute significantly to the continuous increase in coastal vulnerability to adverse environmental conditions and would impair its sustainable development.

3. The systems that would be most vulnerable to higher temperature and sea level rise and to the potential changes of precipitation are (independently of time scale):

   (a) water resources, because of more winter-spring rainfall, with increased torrential rains and winter runoff (less snow), increased evaporation during longer, drier summers, affecting the water cycle, and thereby agriculture, settlements, tourism, and water-intensive industries;

   (b) water quality, because of salinisation of groundwater and increases in temperature and evaporation, salt penetration near the sea due to sea level rise (exacerbated by over-pumping);

   (c) soil erosion because of soil changes, decreased vegetation cover, less humus, and more torrential rainfall;

   (d) decline in natural vegetation cover, due to changes in species and communities and also to forest fires. Considerable alterations are likely in natural ecosystems, although they cannot be specified in any detail yet;

(e) alterations to coastal morphology, both in the form of open beaches especially in small cliff-bound bays and of built-up sea fronts (port structures, seawalls, buildings). By the middle of the next century the impact of sea level rise on coastal settlements and infrastructure could be considerable, as in Syria most are only slightly above present sea level;

(f) energy consumption both civilian and industrial is likely to increase; and

(g) human health and comfort, especially in the urban agglomerations may decline, due to increased evaporation, and relative humidity, and an increase in pests and diseases.

4. On the other hand a CO_2 richer atmosphere could be beneficial for agriculture and fisheries, although estimation of quantitative effects is problematic.

In conclusion, although it may be possible to foresee a series of impacts, it is difficult to estimate their magnitude and timing. However, it may be assumed that generally the intermediate consequences of climate change for the Syrian coastal region, within the first half of the next century, will be modest, and could be borne through proper management of the coastal region, supported by technological advances.

4. RECOMMENDATIONS FOR ACTION

4.1. Preventive policies and measures

Taking into account: the present high level of uncertainty that accompanies the temperature, rainfall and sea level scenarios; that it will take another decade at least before better forecasts can be made of the trends in climate change; that there is still a considerable lack of data and of specific impact studies; one might wonder whether it is possible and/or practical to recommend actions for something that may become significant only in two generations time.

The Task Team has taken the view that appropriate actions over the next few years would be those that could prepare society for the eventual changes, by: keeping control of human activities and use of resources, and minimising the effects of climate and sea level related hazards. Unless there is sustainable coastal zone management, global warming and sea level rise will certainly exacerbate present mismanagement and man-made environmental problems.

Therefore the best policy option in the forthcoming two decades appears to be to create a basis for disaster avoidance and mitigation and to enhance preparedness for future events by implementing integrated coastal zone management.

Firstly, there is a need to acquire more specific data and to monitor a number of physical, ecological and social variables, which would at the same time contribute to making coastal zone management more sustainable and to improving the evaluation of climate change impacts. The most pertinent data/studies that are missing are:

(a) physical oceanographic data which could be related to marine ecosystems on the one hand and to coastal dynamics on the other. The main parameters that need to be analyzed are wave direction and height, tidal range, vertical distribution of salinity and temperature;

(b) coastal morphology data: width, thickness of the beach, rates of erosion or accretion, the nature and source of sands, sand budgets; land subsidence versus uplift; the behaviour of beaches in relation to seasonal wave action and storm surges; and

(c) data on marine ecosystems and processes.

Secondly, in the context of integrated planning for the coastal region:

(a) in regard to sea level rise, calculations must be made about waste outfalls to the sea, and for shore protection and management to identify which stretches could be vulnerable and which solutions would best apply (site specific versus wider spaced applications). Such evaluations should include evaluation of the costs and negative effects of defensive structures for alternative proposals;

(b) introduction of zoning regulations that would take into account the economic cost of restructuring and rebuilding, and control of beach erosion;

(c) it will be necessary to establish air pollution monitoring stations in the coastal region, especially in areas surrounding the industrial plants and the generating stations and harbours. There must also be marine based stations for monitoring of pollution of the marine environment. Decision makers must adopt procedures to control pollution. This must be taken into account in the future planning of the coastal region, including conversion as far as possible to renewable energy sources such as solar and wind; and

(d) advance environmental impact assessment for any proposed activities including industrial, urban, tourist or agricultural expansion, and water systems should be undertaken.

4.2. Adaptive policies and measures

Climate related long term actions that would prepare for adaptation to changes, if these become certain and inevitable, are:

1. Climate information. Attention must be drawn to the potential changes in the frequency and severity of extreme events. Given the non-linear relationship between changes in mean and changes in extreme events, more research is needed to investigate the behaviour of extreme events in a warmer world;

2. Managed ecosystems. It would be very useful to establish a vegetation and agricultural information system, giving details of how each crop responds to climate stresses, and of the crops potentially better suited to future conditions;

3. Water resources. Increased understanding of relations between climate variability and hydrological responses must be developed, in order to produce improved procedures for operating water management systems;

4. Renewable energy sources require much higher priority in national energy programmes. Research, development and demonstration projects should be funded to ensure their rapid development and implementation; and

5. International co-operation. As the drastic changes and problems are global, cooperation with all countries and regions in monitoring, scientific research, and standards concerning transboundary natural resources and environmental interference should be developed.

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ANNEX

TEMPERATURE AND PRECIPITATION SCENARIOS FOR THE NORTH-EASTERN MEDITERRANEAN

Report to the UNEP Co-ordinating Unit for the Mediterranean Action Plan

March 1992

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TEMPERATURE AND PRECIPITATION SCENARIOS FOR THE NORTH-EASTERN MEDITERRANEAN

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SUMMARY

We have applied the methods developed by Kim et al. (1984) and Wigley et al. (1989) to the problem of constructing sub-grid-scale climate change scenarios for the north-eastern Mediterranean area. Regression equations were developed to predict station temperature and precipitation anomalies from regionally-averaged climate anomalies. We proceeded to substitute GCM perturbed-run minus control-run values of temperature and precipitation in the regression equations to obtain a prediction of the change due to the greenhouse effect at each station. The results were scaled by the equilibrium temperature of each of the four GCMs and an average for the four models obtained. The procedure was repeated for every station in the data set, and the results contoured to produce a scenario for the north-eastern Mediterranean area.

Annual and seasonal scenarios for both temperature and precipitation change were produced. For temperature, the greatest sensitivity to the greenhouse effect was found in the mainland areas to the north-east of the study region. Temperature increases less than the global mean temperature change were indicated for the south-west of the study region.

The scenarios for precipitation are much more difficult to evaluate. At the annual level, precipitation is shown to increase in the west and east, and to increase in the south-east, by up to 6% per °C global temperature change. Apart from western Turkey, the mainland coastal regions are all shown to experience a reduction in precipitation, to a maximum of -2 to -6% per °C global temperature change over the central southern Turkish coast and Cyprus. The problems associated with the construction of regional scenarios of precipitation change associated with the greenhouse effect are discussed at length in the Final Report for the UNEP Mediterranean Project. The confidence that we can place in sub-grid-scale scenarios of precipitation is low.

1. THE USE OF GCMS IN REGIONAL SCENARIO DEVELOPMENT

It is generally accepted that the results from General Circulation Models (GCMs) offer the best potential for the development of regional climate scenarios. They are the only source of detailed information on future climates which can extrapolate beyond the limit of conditions which have occurred in the past.

GCMs are complex, computer-based, models of the atmospheric circulation which have been developed by climatologists from numerical meteorological forecasting models. The standard approach is to run the model with a nominal "pre-industrial" atmospheric CO_2 concentration (the control run) and then to rerun the model with doubled (or sometimes quadrupled) CO_2 (the perturbed run). In both, the models are allowed to reach equilibrium before the results are recorded. This type of model application is therefore known as an equilibrium response prediction.

The fact that the GCMs are run in equilibrium mode must in itself be regarded as a potential source of inaccuracy in model predictions. It can be argued that the predicted regional patterns of climate change will differ from those that will occur in a real, transient response world. This is because equilibrium results ignore important oceanic processes, not least ocean current changes, differential thermal inertia effects between different parts of the oceans and between land and ocean, and changes in the oceanic thermohaline circulation. Transient response predictions, where the CO_2 concentration increases gradually through the perturbed run and where the oceans are modelled using ocean GCMs, and which therefore should provide a more realistic estimate, are becoming available. However, the complexity of the problem in relation to present-day computing capability casts doubt on the reliability of the results, and this is likely to remain the case over the next decade. The present study restricts itself, therefore, to the use of results from equilibrium GCM experiments.

The results from four GCMs developed for climate studies are used in this report. These four are from the following research institutions:

- UK Meteorological Office (UKMO)
- Goddard Institute of Space Studies (GISS)
- Geophysical Fluid Dynamics Laboratory (GFDL)
- Oregon State University (OSU)

The models vary in the way in which they handle the physical equations describing atmospheric behaviour. UKMO, GISS and OSU solve these in grid-point form whereas GFDL uses a spectral method. All models have a realistic land/ocean distribution and orography (within the constraints of model resolution); all have predicted sea ice and snow; clouds are calculated in each atmospheric layer in all models.

One problem with the application of GCMs to the study of climate impacts is the coarse resolution of the model grid. The grid scale of the four models listed above ranges from 4^o latitude x 5^o longitude (OSU) to 7.83^o latitude x 10^o longitude (GISS). GCMs, therefore, have a spatial resolution of several hundreds of kilometres, which is inadequate for many regional climate change studies, especially in areas of high relief. We present here a set of high resolution scenarios for the north-eastern Mediterranean, based on the statistical relationship between grid-point GCM data and observations from surface meteorological stations.

2. CONSTRUCTION OF SUB-GRID-SCALE SCENARIOS

Kim et al. (1984) looked at the statistical relationship between local and large-scale regionally-averaged values of two meteorological variables: temperature and precipitation. They then used these relationships, developed using principal component analysis techniques, to look at the response of local temperature and precipitation to the predicted change at GCM grid points. The area of study was Oregon State. Although the paper contains certain statistical flaws, the underlying idea of relating local and large-scale data statistically is sound. The method of Kim et al. has been extended and refined by Wigley et al. (1990) and by Wilks (1989).

The methods of Kim et al. and Wigley et al. have been modified for application in the Mediterranean region. In the model validation exercise carried out for the Mediterranean Project (see Final Report) it was established that no single GCM can be identified as being always the best at simulating current climate. This being the case, there is little merit in presenting scenarios based on only one model. Presentation of scenarios for each of the four models avoids the issue, since the task of deciding which model is 'best', and/or of synthesizing the information to obtain a best estimate, is left to the impact analyst. We have therefore combined the information from the four models into a single scenario for each variable, according to the method described below.

The problem with presenting the scenarios in this form is that the results may be biassed by the different equilibrium responses of the individual models. The global warming due to $2xCO_2$ for the four GCMs ranges between 2.8^oC for the OSU model and 5.2^oC for the UKMO model run. We would therefore expect that the warming indicated by the UKMO GCM for the Mediterranean Basin will be greater than that suggested by the OSU model, even though the sensitivity of the region to climate change when compared to the global sensitivity might be the same. The individual model perturbations have therefore been standardized by the equilibrium (global annual) temperature change for that model, prior to the calculation of the four-model average.

We required a generalized computer program that would be applicable throughout this geographically complex area, and could be used with meteorological records of variable length and density. After investigating a number of approaches to the problem, we adopted the procedure summarized below:

1. Data sets of monthly mean temperature and total precipitation have been compiled for the area surrounding the Mediterranean Basin. Stations used in this study of the north-eastern Mediterranean are listed in Appendix 1. Where possible, each record should be complete for the period 1951-88. Any station with a record length less than 20 years in the period 1951-88 for over six months out of twelve was immediately discarded.

2. Then, for every valid station, the temperature and precipitation anomalies from the long-term (1951-88) mean were calculated. For this part of the work, which is the first step in the construction of the regression equations (the callibration stage), only the data for 1951-80 were used. The 1981-88 data were retained to test the performance of the regression models (the verification stage, see Final Report). For the calculation of the temperature anomaly At_{ij}, the simple difference was used:

$$At_{ij} = t_{ij} - T_j$$

where t_{ij} is the mean temperature of month j in year i, and T_j is the long-term mean for month j. The precipitation anomaly Ap_{ij} was expressed as a ratio of the long-term mean:

$$Ap_{ij} = (p_{ij} - P_j)/P_j$$

where p_{ij} is the monthly total precipitation in month j of year i, and P_j is the long-term mean for that month. If P_j is less than 1mm, then this equation is modified to:

$$Ap_{ij} = (p_{ij} - P_j)/1.0$$

3. The individual station anomalies are used to calculate regionally-averaged anomalies. The procedures described from here to the end of Point 6 are station-specific, and must be repeated for each station in the data set.

   A 5^o latitude x 5^o longitude square is centred over the station for which regression equations are to be developed (the predicted station). All the stations which fall within this square are used to calculate the regional averages. If the number of stations is less than three, for temperature, or four, for precipitation, the procedure is halted. For temperature, the anomalies from all stations in the 5^o x 5^o square are averaged month-by-month to produce an area-average time series. For precipitation, the substantial degree of spatial variability makes it advisable to area-weight the station anomalies before calculating the regional mean for each month. To do this, the 5^o x 5^o region is divided into 20 x 20 smaller squares. The precipitation anomaly value assigned to a particular square is that of the station nearest to it (with the restriction that the distance separating a square from its nearest station should be no greater than 1^o - where the distance is greater the square is ignored). The area average is then the mean of the values in the 400 (or fewer, if any fail the minimum distance criterion) squares. This method is similar to the standard Thiessen polygon method.

4. Regression analyses were performed using station temperature and precipitation anomalies as the predictands. These analyses were carried out on an annual and seasonal basis: winter (December, January, February), spring (March, April, May), summer (June, July, August) and autumn (September, October and November). By considering the monthly values as separate observations within each season, we were able to extend the number of observations and so preserve a high number of degrees of freedom. The predictor variables are the regionally-averaged anomalies of temperature and precipitation.

5. In order to determine the perturbation due to the greenhouse effect at each station, the results from GCMs were employed. It is assumed that a GCM grid-point temperature or precipitation value is equivalent to a regionally-average value derived from observational data. For each of the four GCMs (GFDL, GISS, OSU and UKMO), the perturbed run and control run grid-point temperature (t) and precipitation (p) values are interpolated to the station position. Then, we obtain, for temperature:

$$Atm_i = t_i(2 \times CO_2) - t_i(1 \times CO_2)$$

where Atm is the perturbation due to CO_2 or the 'temperature anomaly' for model i and, for precipitation:

$$Ptm_i = [p_i(2 \times CO_2) - p_i(1 \times CO_2)] \times 100/p_i(1 \times CO_2)$$

where Ptm is the standardized perturbation due to CO_2 or the 'precipitation anomaly'.

The values for Atm and Ptm for each GCM are then substituted in the regression equations to obtain a prediction for the station perturbation of temperature (^{o}C) and precipitation (%) due to CO_2.

6. The predicted change in temperature and precipitation for each model is divided by the equilibrium (global mean) temperature change for that model. The results are then averaged across the four models to obtain a composite value.

7. The procedures from Points 3 to 6 is repeated for each station throughout the Mediterranean. The results can then be plotted and contoured to obtain a map of the expected patterns of temperature and precipitation change due to the greenhouse effect.

In order to arrive at this procedure, a rigorous investigation of the validity of the method has been carried out. In particular, we have looked at:

- the use of other predictor variables in the regression equations

- performance and verification of the regression equations

- autocorrelation in the data

- multicollinearity in the predictor variables

These aspects are discussed in detail in the Final Report.

3. CLIMATE CHANGE SCENARIOS FOR THE NORTH-EASTERN MEDITERRANEAN

The sub-grid-scale scenarios, constructed according to the method outline in Section 2, are shown in Figs. 1-5. The temperature perturbations are presented as the model average change, in degrees Celsius, per °C global annual change. The precipitation perturbations are shown as the percentage change for each 1°C global annual change. This procedure is described in greater detail, and the approach justified, in Section 2.

The problem with expressing the scenarios in this form is then to scale the values up (or down) in relation to some realistic estimate of the temperature perturbation to be expected from the greenhouse effect. The IPCC Report (Houghton et al., 1990) provides one such family of estimates. For their Business-as-Usual scenario of emissions, the likely increase of global mean temperature by the year 2050 is predicted to be about 1°C above the present level. By the end of next century, the increase is estimated at 3°C above present-day. On this basis, the temperature and precipitation scenarios for the north-eastern Mediterranean presented in this report can be related directly to changes between now and the year 2050.

The scenarios for changes at the annual level are shown in Fig. 1. In the north and east of the region the temperature change is indicated to be greater than the global change i.e. more than 1°C per °C global warming. In the south and west the sensitivity should be slightly below the global value. The boundary between the two lies approximately along the coast. The greatest temperature increase (1.2-1.5°C per °C global change) is indicated for the interior of Turkey and the countries bordering the eastern Mediterranean and the north coast of Cyprus. Lowest changes (0.7-0.8°C per °C global warming) are shown over the southeastern Dodecanese Islands, including Rhodes, and the extreme western tip of Cyprus. Precipitation is predicted to increase in the west and the extreme east of the study region, by up to 6% per °C global temperature change. Apart from western Turkey, the mainland coastal regions are all shown to experience a reduction in precipitation, to a maximum of -2 to -6% per °C global temperature change over the central southern Turkish coast and Cyprus.

In the winter months of December, January and February (Fig. 2) the predicted temperature changes are between 1.8°C and 0.5°C per degree global change. Lowest sensitivities are found along the south-western Turkish coast and the adjoining Greek Islands. Highest changes (1.4°C-1.8°C per °C global change) are indicated for the interior of Turkey. Winter precipitation shows a pronounced decline in the south-west of the study region (between -6% and -15% per °C global temperature increase). However, increased precipitation is predicted for Turkey, eastern Cyprus and the eastern Mediterranean coast. The greatest increase is shown to be in the region of 2-6% per °C.

Spring scenario temperature changes (Fig. 3) follow the same pattern as those indicated by the annual and winter scenarios: a trend of decreasing sensitivity to the greenhouse effect from north-east to south-west. Precipitation amounts are predicted to increase in most areas with the exception of Cyprus and the adjoining coasts of Turkey and the eastern Mediterranean. The greatest increases are shown in the south-west and south-east of the region, between 6% and 15% per °C.

The temperature scenario for summer (June, July and August) is substantially different from the annual pattern shown in Fig. 1. Only limited areas have a sensitivity less than the global value: the extreme west of the study region including eastern Crete, the south-eastern Mediterranean coast and part of eastern Turkey. Elsewhere, the sensitivity is suggested to be higher than the global level, rising as high as 1.2-1.6°C per °C global change over most of Cyprus, central Turkey and parts of the eastern Mediterranean lands. For the precipitation scenario, it was not possible to arrive at a prediction for the north-east of the study region, because the regression relationships were too weak. However, where a prediction is available, it suggests a decrease in precipitation for the extreme north-west and south-east of the study region. Elsewhere, precipitation is shown to increase, by as much as 12-26% per °C global temperature change over central Crete, the Cyclades and the northern Dodecanese.

The range and pattern of autumn temperature changes, as indicated by the scenario of Fig. 5, are close to the annual values, with the greatest sensitivity in the north-east of the study region and the lowest in the south-west. Precipitation is indicated to increase in most areas, and particularly in the extreme north-west and the east of the study region where the indicated changes are +6% to +15% per °C global temperature change. Lower precipitation is suggested for the south-west of the study region, and for the land areas adjoining the north-eastern Mediterranean.

Fig. 1 Regional climate scenarios for the north-eastern Mediterranean: annual

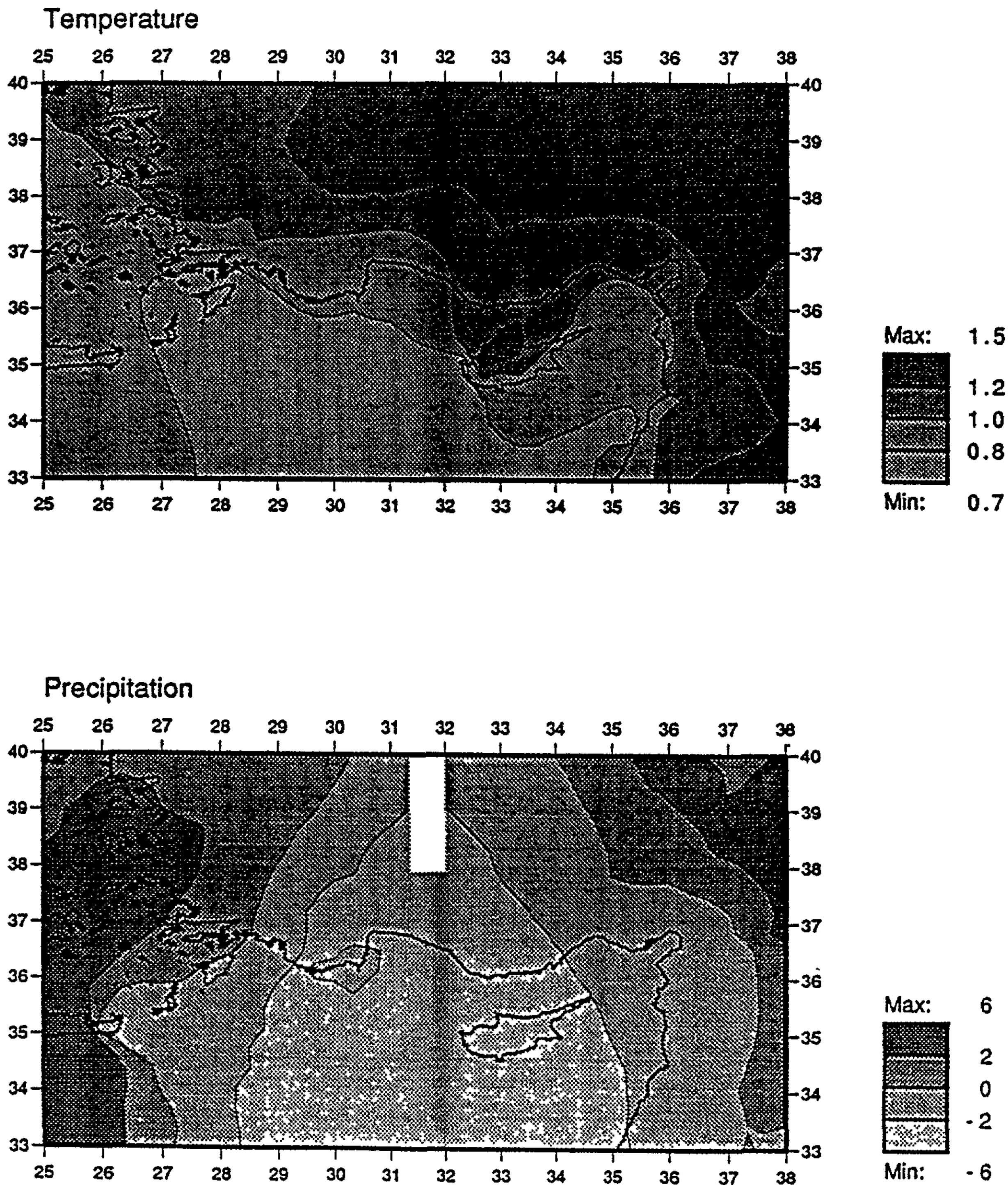
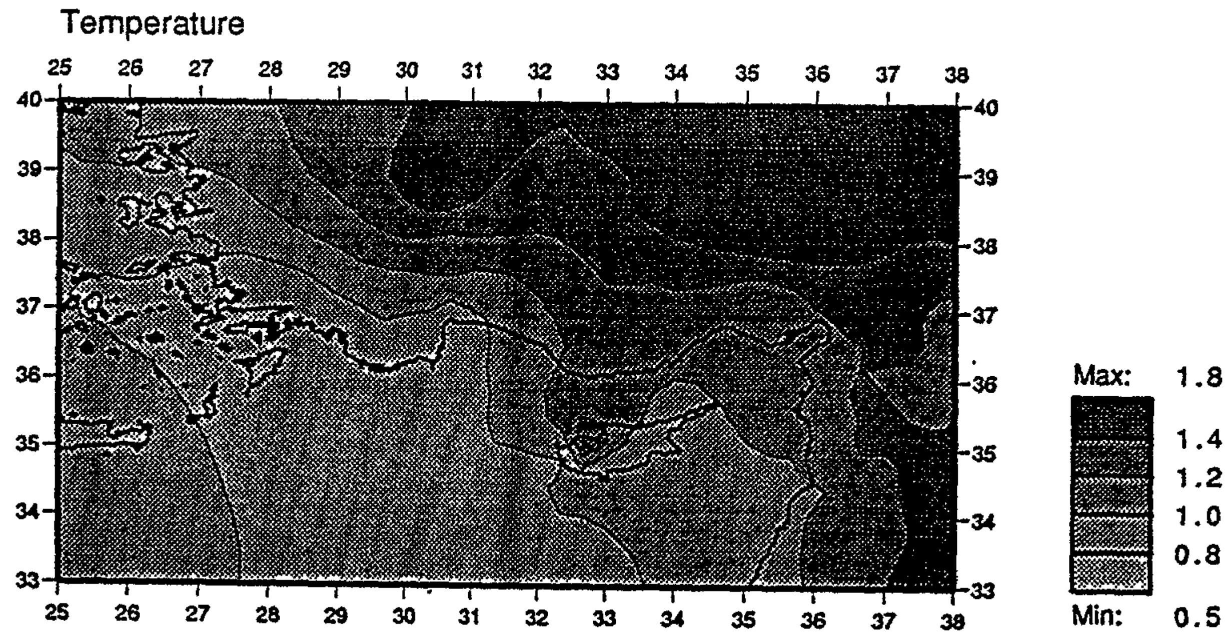


Fig. 2 Regional climate scenarios for the north-eastern Mediterranean: winter



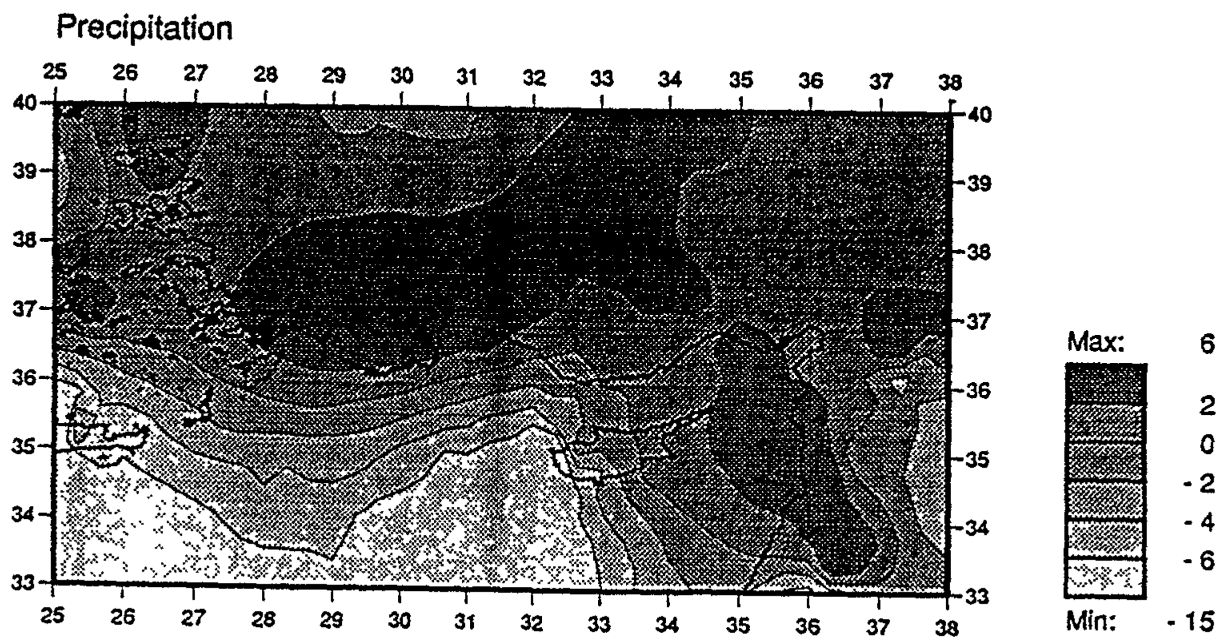
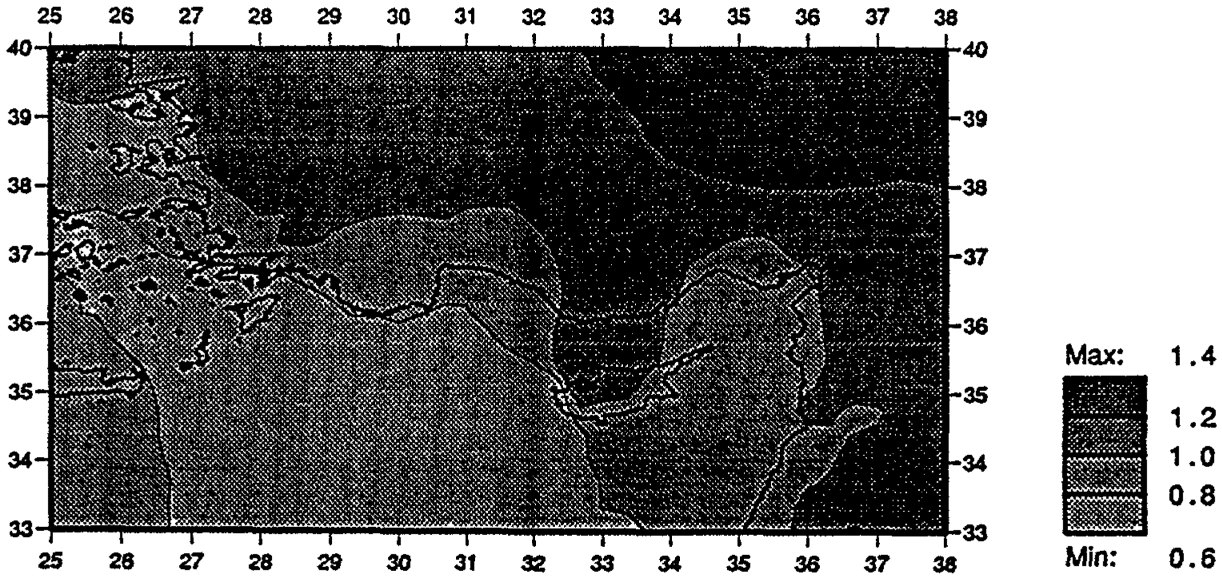


Fig. 3 Regional climate scenarios for the north-eastern Mediterranean: spring

Temperature



Precipitation

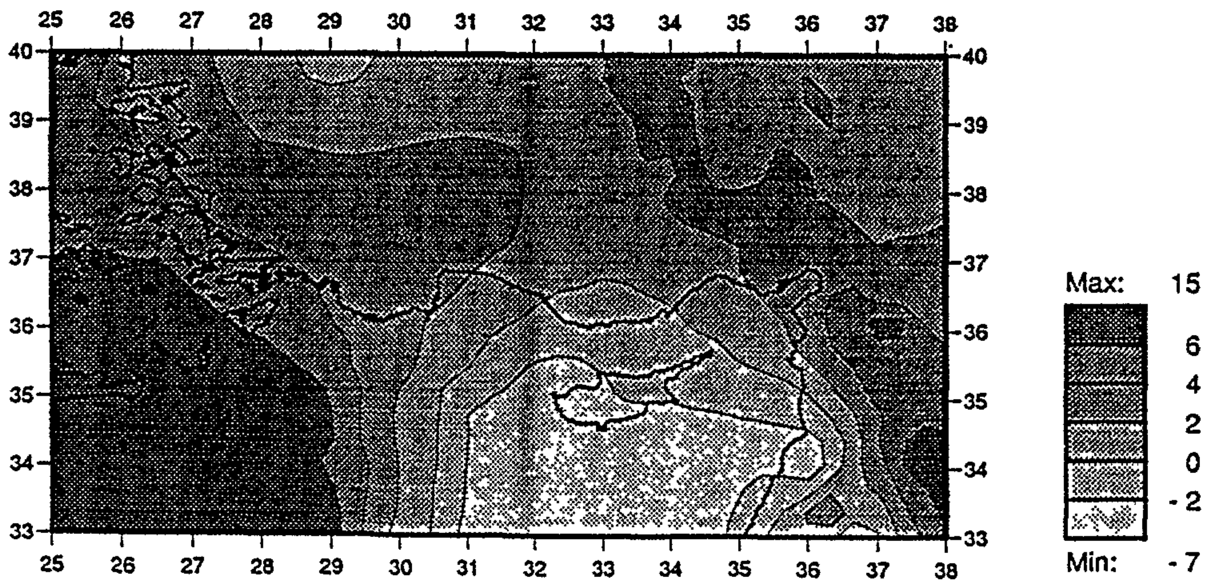
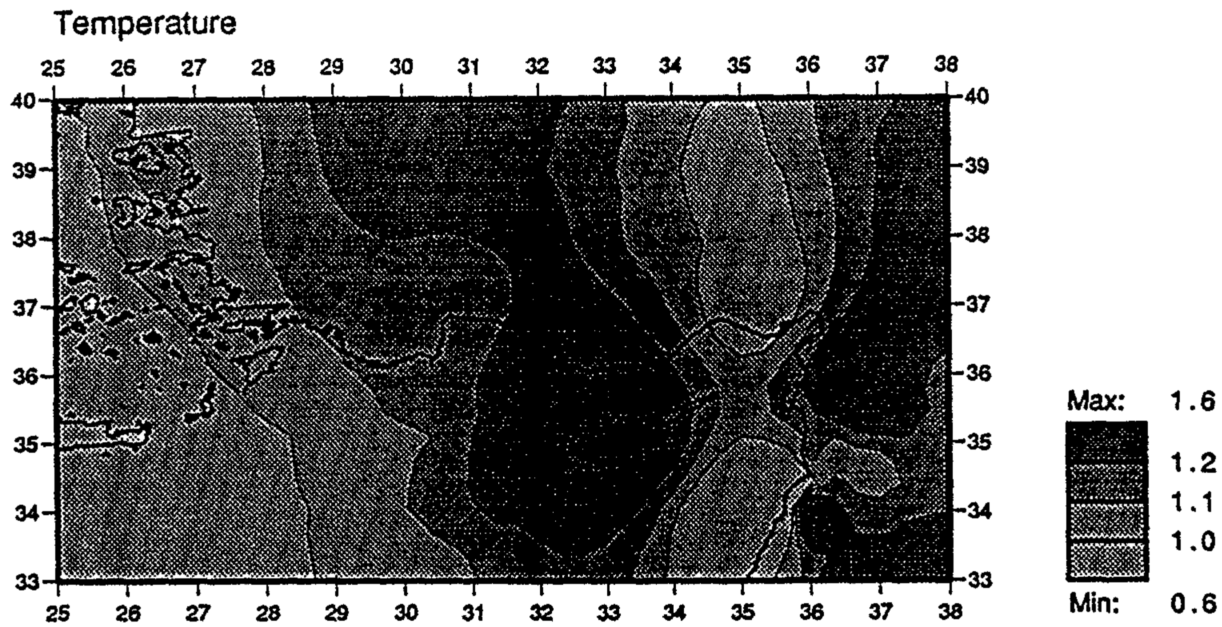


Fig. 4 Regional climate scenarios for the north-eastern Mediterranean: summer



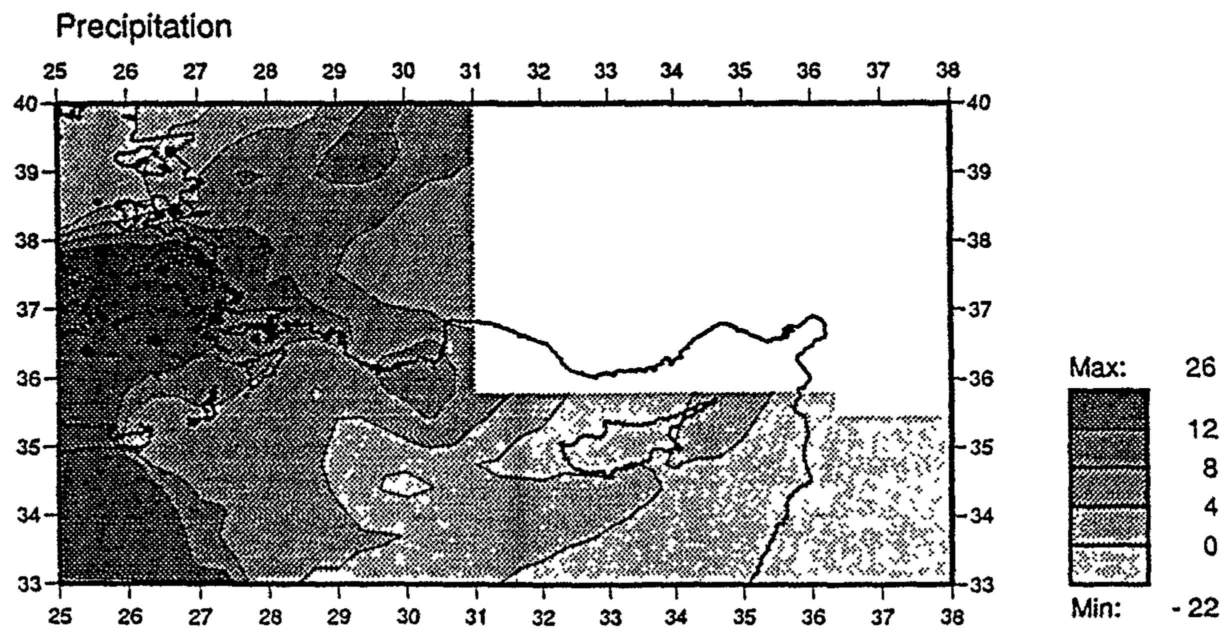
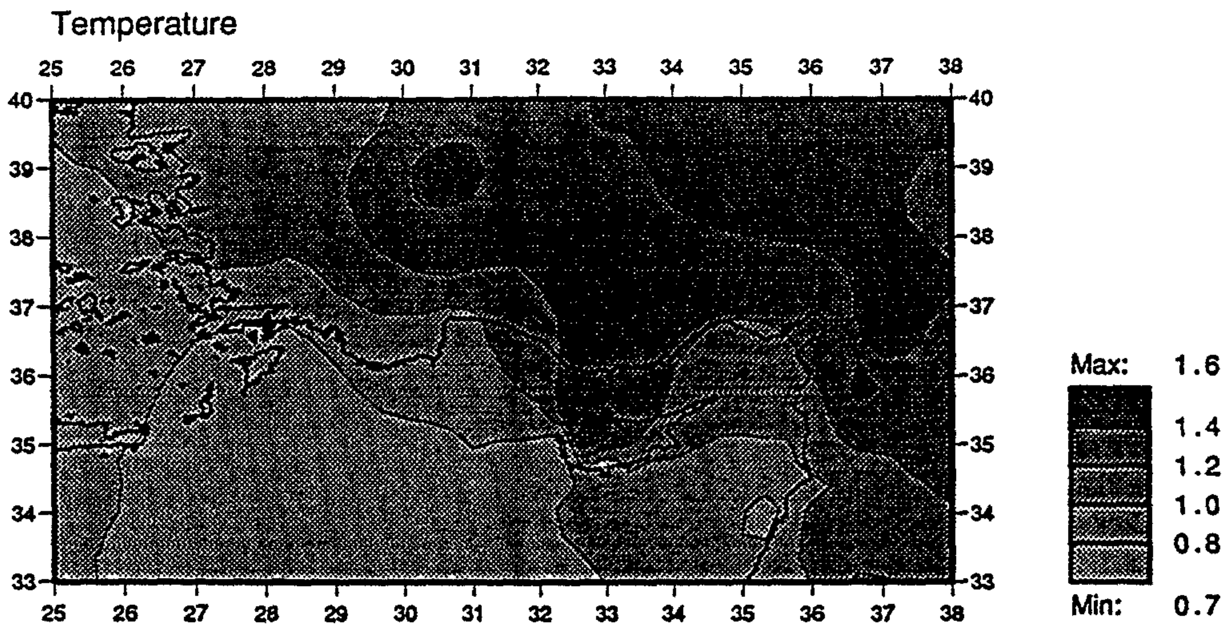
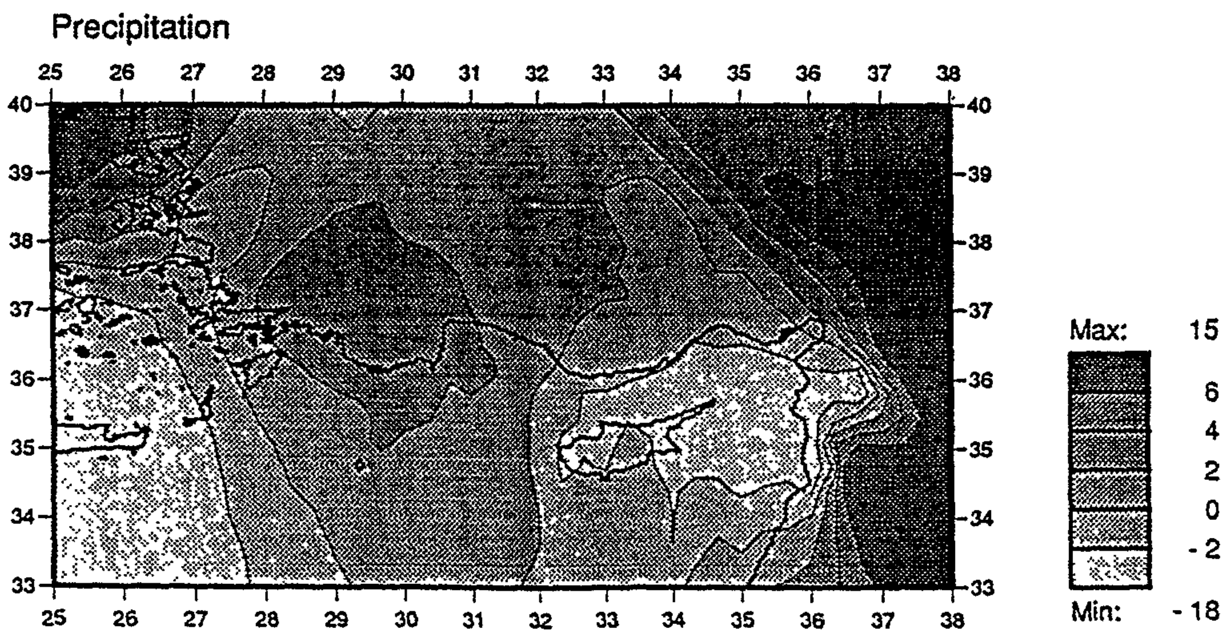


Fig. 5 Regional climate scenarios for the north-eastern Mediterranean: autumn





4. CONCLUSIONS

We have applied the methods developed by Kim et al. (1984) and Wigley et al. (1989) to the problem of constructing sub-grid-scale climate change scenarios for the north-eastern Mediterranean area. Regression equations were developed to predict station temperature and precipitation anomalies from regionally-averaged climate anomalies. We proceeded to substitute GCM perturbed-run minus control-run values of temperature and precipitation in the regression equations to obtain a prediction of the change due to the greenhouse effect at each station. The results were scaled by the equilibrium temperature of each of the four GCMs and an average for the four models obtained. The procedure was repeated for every station in the data set, and the results contoured to produce a scenario for the north-eastern Mediterranean area.

Annual and seasonal scenarios for both temperature and precipitation change were produced. For temperature, the greatest sensitivity to the greenhouse effect was found in the mainland areas to the north-east of the study region. Temperature increases less than the global mean temperature change were indicated for the south-west of the region.

The scenarios for precipitation are much more difficult to evaluate. At the annual level, precipitation is shown to increase in the west and east, and to increase in the south-east, by up to 6% per °C global temperature change. Apart from western Turkey, the mainland coastal regions are all shown to experience a reduction in precipitation, to a maximum of -2 to -6% per °C global temperature change over the central southern Turkish coast and Cyprus. The problems associated with the construction of regional scenarios of precipitation change associated with the greenhouse effect are discussed at length in the Final Report for the UNEP Mediterranean Project. The confidence that we can place in sub-grid-scale scenarios of precipitation is low.

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APPENDIX 1

STATIONS USED IN SCENARIO CONSTRUCTION FOR THE NORTH-EASTERN MEDITERRANEAN

BULGARIA

	Station	E	N	HT	PRN	TEM	P%	T%
1.	SOFIA	23.3	42.7	564	1951-1989	1951-1979	67	72
2.	PLOVDIV	24.8	42.2	160	1951-1970	1951-1970	92	92
3.	BOURGAS	27.5	42.5	28	1951-1989	1951-1979	63	70

CYPRUS

	Station	E	N	HT	PRN	TEM	P%	T%
4.	PAPHOS	32.4	34.8	10	1951-1989	1951-1989	100	100
5.	PRODHROMOS	32.8	35.0	1380	1967-1989	1959-1989	98	99
6.	LIMASSOL	33.0	34.7	10	1951-1989	1951-1989	100	98
7.	NICOSIA	33.4	35.2	160	1951-1989	1951-1989	100	100
8.	LARNACA	33.6	34.9	3	1951-1989	1951-1989	100	100

EGYPT

	Station	E	N	HT	PRN	TEM	P%	T%
9.	SALLOUM	25.2	31.5	6	1951-1987	1951-1987	99	89
10.	SIDI-BARANI	26.0	31.6	23	1951-1987	1951-1987	100	99
11.	MERSA-MATRUH	27.2	31.3	30	1951-1989	1951-1987	99	97
12.	NOUZHA	30.0	31.2	7	1951-1987	1951-1975	100	56
13.	ROSETTA	30.4	31.4	3	1951-1987	-	74	0
14.	DAMIETTA	31.8	31.4	5	1951-1987	-	99	0
15.	PORT-SAID	32.3	31.3	6	1951-1987	1951-1987	99	98
16.	SAKHA	30.9	31.1	n/a	1951-1987	-	96	0
17.	TANTA	30.9	30.8	8	1961-1986	1951-1986	100	100
18.	ZAGAZIG	31.5	30.6	13	1961-1986	1951-1986	100	100
19.	CAIRO	31.4	30.1	74	1951-1989	1951-1986	99	83
20.	GIZA	31.2	30.0	22	1951-1986	1975-1986	100	100
21.	ISMAILIA	32.3	30.6	12	1951-1986	1951-1986	64	42

GREECE

	Station	E	N	HT	PRN	TEM	P%	T%
22.	MIKRA	23.0	40.5	61	1951-1989	1951-1987	96	100
23.	LARISSA	22.4	39.6	74	1951-1989	1951-1987	94	97
24.	AGXIALO	22.8	39.0	n/a	1956-1987	1956-1987	100	98
25.	TRIPOLIS	22.2	37.6	660	1957-1987	1957-1987	100	100
26.	KALAMATA	22.1	37.0	5	1951-1989	1951-1988	94	95
27.	TANAGRA	23.5	38.3	n/a	1957-1986	1957-1986	99	99
28.	ATHENS	23.7	38.0	107	1951-1989	1951-1988	98	97
29.	HELLENIKON	23.7	37.9	10	1951-1989	1951-1987	84	80
30.	KYTUIRA	23.0	36.2	n/a	1955-1987	1955-1987	100	100
31.	SKYROS	24.6	38.9	5	1955-1987	1955-1987	100	100
32.	MILOS	24.5	36.7	n/a	1955-1987	1955-1987	99	100
33.	ALEXANDROUPOLI	25.8	40.9	3	1951-1987	1951-1987	100	100
34.	MITILIA	26.4	39.2	n/a	1955-1987	1957-1987	100	99
35.	NAXOS	25.5	37.1	9	1955-1987	1955-1987	100	100
36.	SOUDA	24.1	35.6	161	1958-1989	1958-1986	97	97
37.	ANOGIA	24.9	35.3	n/a	1951-1985	-	96	0
38.	HIRAKLION	25.2	35.3	48	1955-1986	1951-1988	97	97
39.	IERPETRA	25.8	35.0	n/a	1956-1987	1956-1987	99	99

40. SITIA	26.1	35.2	28	1951-1985	-	87	0
41. KARPATHOS	27.2	35.5	20	1971-1988	1971-1988	95	95
42. RHODES	28.1	36.4	12	1955-1988	1955-1988	100	100

ISRAEL

Station	E	N	HT	PRN	TEM	P%	T%
43. LOD	34.9	32.0	49	1951-1989	1951-1988	93	100
44. JERUSALEM	35.2	31.8	809	1951-1989	1951-1980	97	100

JORDAN

Station	E	N	HT	PRN	TEM	P%	T%
45. IRBID	35.9	32.6	585	1955-1989	1955-1989	100	100
46. RUWASHED	38.2	32.5	686	1960-1989	1961-1989	100	100
47. AMMAN	36.0	32.0	771	1951-1989	1951-1989	100	100
48. DEIR-ALLA	35.6	32.2	-224	1952-1989	1952-1989	100	100
49. MAAN	35.8	30.2	1069	1960-1989	1960-1989	100	100
50. WADI-YABIS	35.6	32.4	-200	1960-1989	1960-1989	96	98
51. MAFRAQ	36.3	32.4	686	1960-1989	1960-1989	100	100
52. ER-RABBAH	35.8	31.3	920	1960-1989	1961-1989	100	95
53. JORDAN-UNIV	35.9	32.0	980	1960-1989	1961-1989	100	90

LEBANON

Station	E	N	HT	PRN	TEM	P%	T%
54. BEIRUT	35.5	33.9	24	1951-1985	1951-1985	80	84
55. RAYACK	36.0	33.9	921	1951-1984	1951-1985	76	80
56. TRIPOLI	36.0	34.6	10	1951-1982	1951-1980	77	76

LIBYA

Station	E	N	HT	PRN	TEM	P%	T%
57. DERNA	22.6	32.7	9	1951-1988	1951-1988	31	50
58. TOBRUQ	24.0	32.1	14	1951-1973	-	100	0
59. ADEM	23.9	31.9	155	1951-1988	1951-1975	96	93

SYRIA

Station	E	N	HT	PRN	TEM	P%	T%
60. ALEPPO	37.2	36.2	393	1951-1989	1952-1988	97	99
61. LATTAKIA	35.8	35.6	9	1952-1989	1952-1988	90	94
62. DEIR-EZZOR	40.2	35.3	212	1951-1989	1952-1988	97	99
63. PALMYRA	38.3	34.6	404	1955-1989	1955-1988	97	99
64. DAMASCUS	36.2	33.5	724	1951-1989	1951-1988	97	99
65. SAFITA	36.1	34.8	n/a	1959-1988	1959-1988	100	100
66. IDLEB	36.7	35.9	n/a	1955-1988	1957-1988	100	100
67. HAMA	36.8	35.1	n/a	1955-1988	1956-1988	100	100
68. HOMUS	36.7	34.8	n/a	1955-1988	1955-1988	100	100
69. NABEK	36.7	34.0	n/a	1955-1988	1959-1988	100	100
70. SUEIDA	36.6	32.7	n/a	1958-1988	1958-1988	100	100
71. TELSHEHAB	36.0	32.7	n/a	1958-1988	1958-1988	100	100
72. HASAKEH	40.8	36.5	300	1957-1988	1957-1989	100	100
73. KHARABO	36.5	33.5	620	1946-1988	1956-1989	100	100
74. JARABLUS	38.0	36.8	350	1957-1988	1957-1989	100	100
75. JABAL	38.7	33.5	722	1958-1989	1958-1989	100	100
76. MESELMIYIE	37.2	36.3	425	1946-1988	1957-1989	100	100
77. RAQQA	39.0	36.0	250	1957-1988	1958-1989	100	100

78. TARTOUS	35.9	34.9	5	1957-1990	1957-1989	100	100
79. TEL-ABIAD	39.0	36.7	349	1957-1988	1957-1989	100	100

TURKEY

Station	E	N	HT	PRN	TEM	P%	T%
80. EDIRNE	26.6	41.7	48	1951-1989	1951-1988	95	98
81. CANAKKALE	26.4	40.1	3	1951-1989	1951-1988	96	98
82. IZMIR	27.3	38.4	25	1951-1989	1951-1988	96	98
83. MUGLA	28.4	37.2	646	1951-1989	1951-1988	94	96
84. ISTANBUL	29.1	41.0	40	1951-1989	1951-1988	97	98
85. BURSA	29.1	40.2	100	1951-1989	1951-1980	95	97
86. AFYON	30.5	38.8	1034	1951-1989	1951-1988	97	98
87. ISPARTA	30.6	37.8	1043	1951-1989	1951-1988	97	98
88. ANTALYA	30.7	36.9	43	1951-1989	1951-1988	96	98
89. KASTAMONU	33.8	41.4	799	1951-1989	1951-1988	97	98
90. ANKARA	32.9	40.0	894	1951-1989	1951-1988	97	98
91. KONYA	32.5	37.9	1022	1951-1989	1951-1988	93	98
92. KAYSERI	35.5	38.7	1070	1951-1982	1951-1988	97	91
93. ADANA	35.3	37.0	66	1951-1985	1951-1986	95	93
94. SAMSUN	36.3	41.3	44	1951-1989	1951-1988	97	98
95. SIVAS	37.0	39.8	1285	1951-1989	1951-1980	97	100
96. MALATYA	38.3	38.4	998	1951-1989	1951-1988	92	98
97. URFA	38.8	37.1	547	1951-1989	1951-1988	94	96
98. RIZE	40.5	41.0	4	1951-1989	1951-1988	90	96
99. ERZINCAN	39.5	39.7	1215	1951-1989	1951-1988	95	96
0. DIYARBAKIR	40.2	37.9	677	1951-1989	1951-1988	95	98

E - latitude
N - longitude
HT - height above sea level (m)
PRN - length of precipitation record
TEM - length of temperature record
P% - percentage of precipitation record present
T% - percentage of temperature record present